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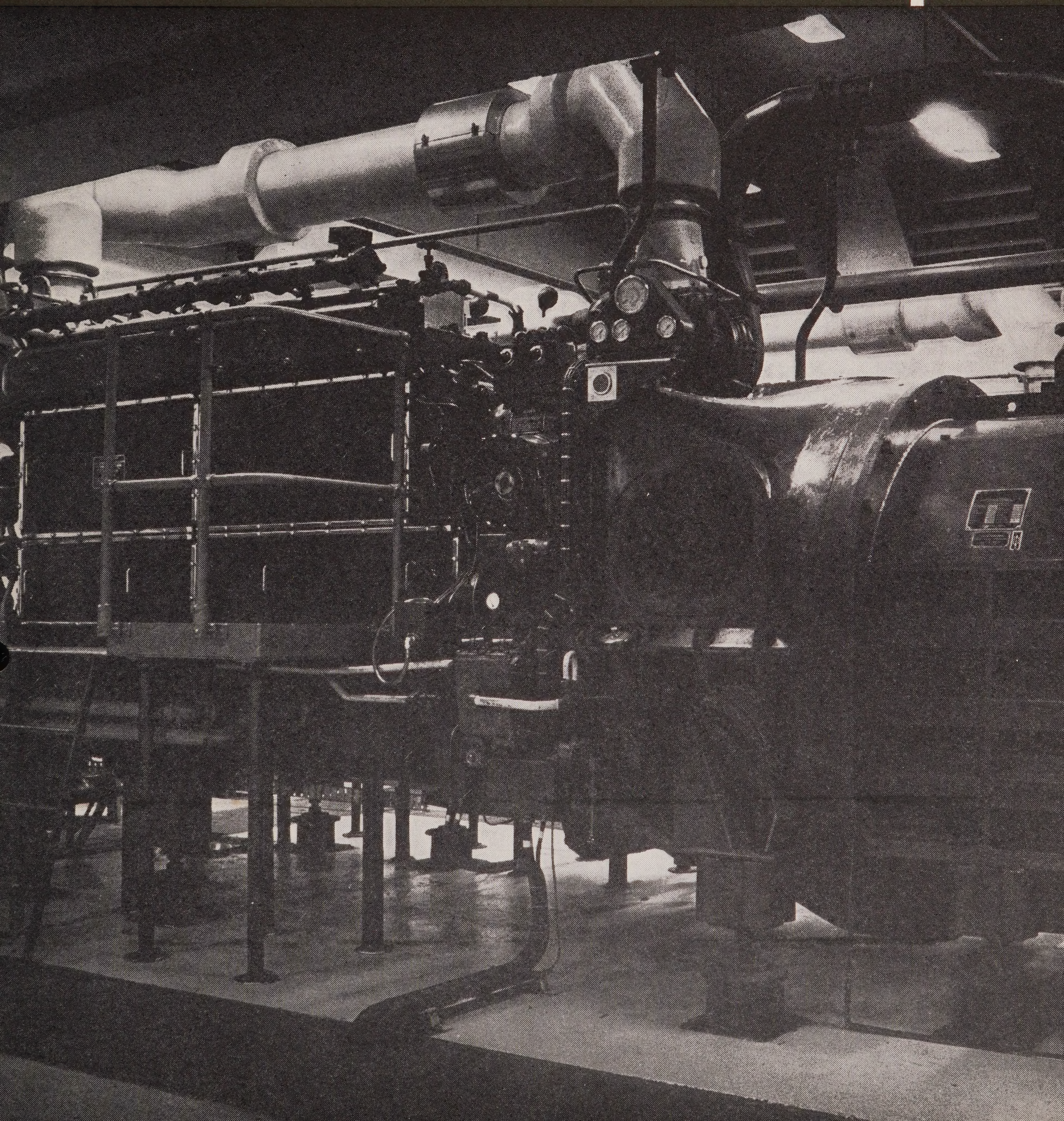
HOSPITAL TECHNICAL MEMORANDUM

11

EMERGENCY ELECTRICAL SERVICES



Department of Health and Social Security: London

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Hospital Technical Memorandum Number 11

Emergency Electrical Services

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I. Foreword

1. Hospitals are increasingly dependent on electricity not only to maintain a safe and comfortable environment for patients and staff but also to run the sophisticated medical equipment which provides life-saving services. Moreover, prolonged interruptions to power supplies can have serious effects on the various supporting services, such as laundries, on which hospitals depend.

2. Hospitals must be able to ensure that they can continue to provide essential services even during prolonged and repeated power cuts.

II. Scope

3. This Technical Memorandum gives guidance on the provision of emergency electricity supplies in hospitals.

4. It is primarily intended to assist those who are concerned with planning the electricity services in new hospitals, but it will also indicate the broad principles against which hospital authorities can examine the emergency supply facilities in existing hospitals and plan for future requirements.

5. In planning improvements to existing facilities which do not meet the standards recommended in this Memorandum, authorities should bear in mind the following priorities:

(i) the protection of life-saving and life-support services such as those found in operating suites, delivery rooms, special care baby units, intensive therapy units and high dependency units where patient monitoring equipment, ventilators, defibrillators, renal dialysis machines, etc., are used;

(ii) the provision of light, heat and, if necessary, ventilation in patient areas;

(iii) essential supporting services.

III. Definitions used in this Memorandum

Emergency supply

6. Any form of electric supply which is intended to be available in the event of a failure of the normal supply.

Standby supply

7. The supply from an engine-driven generator which is arranged to come into operation in the event of a failure of the normal supply.

No-break generator set

8. An engine-driven generator set so designed to enable it to take up the load in the event of a failure of the normal supply without a break in supply.

Static inverter

9. Equipment designed to provide an a.c. output from a d.c. input without the use of moving parts.

Rotary converter

10. Rotary equipment giving an a.c. output from a d.c. input.

Essential circuits

11. Circuits which supply equipment or services which it is essential to keep in operation during power failures and which are so arranged that they can be supplied separately from the remainder of the electrical installation.

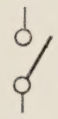
Generator set

12. A diesel engine-driven synchronous a.c. generator with exciter and other essential components.

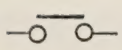
IV. Symbols used in diagrams

Socket outlet.

Indicator lamp.



Switch or isolator.

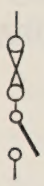


Isolator used as bus-section switch.

Manually operated change-over switch.

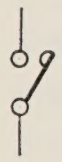
Link with bolted contacts.

Fuse with separable contacts.

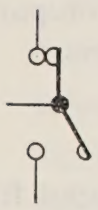


Fuse-switch or switch-fuse.

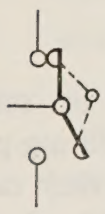
Circuit breaker.



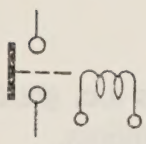
Contactor.



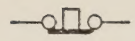
Change-over contactor, B.S.764 type, with contacts shown in the normal position, i.e. with the mains coil energised.



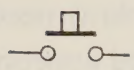
Change-over contactor comprising two contactors with mechanical and electrical interlocks. Contactor shown in the normal position.



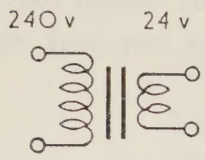
Relay or contactor with operating coil.



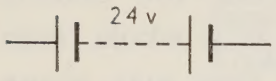
Push-button switch normally closed.



Push-button switch normally open.



Double wound transformer.

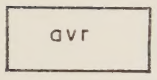


Storage battery.

Horn or hooter.

Synchronous alternating current generator.

Control panel.



Automatic voltage regulator.

Sliprings and brushgear on rotating machine.

Connection to earth conductor or earth electrode.

V. Normal electricity supplies

13. The supply authorities regard hospitals as priority users and make every effort to maintain supplies. Experience indicates that the risk of failure of the normal supply may be higher in country districts where there is more extensive use made of overhead distribution systems. In the case of a general power shortage, however, due either to exceptional demand or reduced supplies, all hospitals may be liable to cuts. Consultation with the Area Electricity Board is necessary to assess the extent to which the normal supply to a hospital will be at risk to interruption from the various causes.

14. Where the hospital electricity supply is obtained from an integrated supply network it will not be possible to obtain a completely independent supply. Most large and new hospitals, however, will take a supply of 11,000 volts to a sub-station within the hospital complex, and it is unlikely that they will be affected by failures involving the local supply network.

15. The additional safeguard against supply failure which can be obtained by having a duplicate supply feeder will depend largely on the supply authority transmission and distribution system in the particular area. The Area Electricity Board will be able to advise on this. Having regard to the importance of maintaining electricity supplies in hospitals, however, the provision of a duplicate supply will be justified where it can be provided at a reasonable cost.

16. The hospital electrical installation should be planned to limit interruptions of the supply due to internal faults as far as is reasonably practicable. This subject is dealt with in greater detail in Hospital Technical Memorandum No. 7: Electrical Services.

VI. Provision of emergency supplies

17. While failures involving the normal supply are likely to be few and of short duration, standby plant should be capable of operating continuously to allow for the possibility of a prolonged supply interruption.

18. Having regard to the high standard of reliability of the normal supply the capacity (and therefore the cost) of standby plant should in general be restricted to that which will enable the hospital to carry out its essential functions when running on the standby supply. Within this general objective the aim should be to simplify the electrical installation as far as is practicable and to avoid unnecessary division into essential and non-essential circuits, particularly with lighting circuits where comparatively small loads are involved.

19. Where new hospitals are built in separate phases, the emergency supply for the whole hospital should as far as is possible be planned at the outset. This will enable, for example, the total standby plant needs to be assessed in the early planning stages and appropriate total accommodation provided even if, where two or more generator sets will eventually be required, they are installed as actually needed.

20. The emergency supply facilities for existing hospitals should also be planned as a whole, even though for various reasons some time may elapse before the full programme can be completed.

21. It is recommended that regional health authorities have available a number of mobile power plants to cover some of their support services needs, the breakdown of permanently installed plant, or to boost installed plant while a hospital is temporarily cut off. These mobile units of course should be strategically located within the region and so equipped and maintained as to enable them to be quickly put into service.

VII. Emergency services—Lighting

General

22. Essential lighting requirements will vary considerably depending on the importance and the nature of the work carried out. In general, however, there will be two categories of emergency lighting, i.e. safety lighting and standby lighting; standby lighting is itself sub-divided into two grades.

Safety lighting

23. The function of safety lighting, previously called skeleton lighting, is to enable essential movement of staff and patients to be carried out in reasonable safety and to assist safe, unobstructed means of escape. It will therefore be required in most, if not all, parts of the hospital. Lighting points will be required for example at intersections of corridors, changes of direction and level, on staircases, exit doors, etc. The lighting must give a positive indication of escape routes where necessary and all signs giving such direction should be adequately lit. After determining these essential locations, the positioning of intermediate lighting points will depend on the floor-to-ceiling height available, obstructions, the desirability of constant spacing and the overall need for a minimum illuminance of 0·20 lux at floor level. In general the higher the intensity of the normal lighting the higher should be the level of the safety lighting. Safety lighting circuits should be routed so as to avoid passing through areas of high fire risk or high fire loading. Safety lighting will be supplied from the automatic start standby generating plant in the event of failure of the normal supply and a short break in supply will occur during the period that the engine is run up to its operating speed. In certain areas, for example on some staircases, where this break is unacceptable, the use of self-contained battery-operated lighting fittings will be justified.

Standby lighting

24. Standby lighting will be provided to enable certain essential activities to be carried out during an emergency. In critical working areas such as in operating suites, delivery rooms and high dependency units the degree and quality of the standby lighting should be equal or nearly equal to that of the normal lighting. Even in these areas, however, considerable reduction in the general lighting may be acceptable. A supply will be available from socket outlets on essential circuits, enabling portable lighting fittings to be used for tasks outside the critical working areas which may require a higher standard of lighting.

25. The two grades of standby lighting recommended are:

Grade (*a*)—lighting of intensity and quality equal or nearly equal to that provided by the normal lighting;

Grade (*b*)—a reduced standard of lighting, e.g. about one-third to one-half the normal standard, sufficient to enable general hospital activities to be properly carried out.

26. The following schedule is intended as a general guide to possible standby lighting requirements:

Department or location	*Area*	*Grade of lighting*
Operating department		
Major operating suites	critical working areas	*Grade* (*a*)
Reception and recovery rooms	general working areas	*Grade* (*b*)
Maternity department		
Delivery rooms Operating rooms	critical working areas	*Grade* (*a*)
Special care baby unit Treatment rooms Nurseries	general working areas	*Grade* (*b*)
Admission suite Reception and administration Ante-natal clinic	general working areas	*Grade* (*b*)
Accident and emergency department		
Minor operating suite Resuscitation and recovery rooms	critical working areas	*Grade* (*a*)
Major treatment rooms	general working areas	*Grade* (*b*)
Orthopaedic and fracture clinic X-ray viewing area Pathology laboratory Reception and waiting	general working areas	*Grade* (*b*)
Administrative department		
Telephone exchange		*Grade* (*a*)
Medical records Central inquiry counter Computer room Principal offices	general working areas	*Grade* (*b*)
Out-patient department and Special treatment clinic		
Operating rooms Treatment areas	critical working areas	*Grade* (*a*)
Dental suite Consulting and examination room Reception and registration	general working areas	*Grade* (*b*)
Dispensary	dispensing areas	*Grade* (*a*)
Patient care areas		
Intensive therapy unit Coronary care unit Burns unit Haemodialysis unit High dependency units	general working areas	*Grade* (*a*)
Bed areas in wards (including psychiatric and geriatric)		
Bed areas in wards, etc.	general working areas	*Grade* (*b*)
Nurses' station Treatment rooms Drug stores and D.D.A. cupboards	general working areas	*Grade* (*a*)
Bathrooms and showers Utility rooms Kitchen	general working areas	*Grade* (*b*)

Department or location	*Area*	*Grade of lighting*
Psychiatric department		
E.C.T. suite	critical working areas	*Grade (a)*
Treatment areas	general working areas	*Grade (b)*
Pathology department	essential working areas (i.e. blood banks, transfusion laboratory)	*Grade (a)*
	general working areas	*Grade (b)*
Rehabilitation department		
Occupational therapy and physiotherapy departments	treatment and general working areas	*Grade (b)*
Diagnostic X-ray department		
Special procedure rooms	critical working areas	*Grade (a)*
X-ray rooms	general working areas	*Grade (b)*
Reception		
Processing and viewing rooms		
Changing and preparation rooms		
Radiotherapy department	critical working areas	*Grade (a)*
	general working areas	*Grade (b)*
Mortuary and post-mortem room	general working areas	*Grade (b)*
Kitchens and dining rooms		
Preparation and cooking area	general working areas	*Grade (b)*
Servery and dining area		
Stores		
Lifts		
Lift cars		*Grade (a)*
Landing lobbies		*Grade (b)*
Grouped services, e.g.		
Laundries	general working areas	*Grade (b)*
HSSD		
Boiler house and plant rooms	working areas	*Grade (b)*

VIII. Emergency services—Power

Socket outlets

27. As a general guide, in any area where standby lighting is provided to enable essential activities to be carried out during an emergency, all socket outlets should also be connected to essential circuits. It is reasonable to assume that only essential equipment will be used in these areas during periods of supply interruption, and hospitals should of course ensure that all possible economies are made in the use of electricity when running on the standby supply. The recommendation that all socket outlets are connected to the essential circuits is made to simplify the electrical installation and also to provide the most convenient choice of sockets at any time. A larger diversity factor should be allowed, however, when assessing the demand on the standby generating plant.

28. Where standby lighting is being provided for the well-being and/or security of the patients, i.e. in long stay, geriatric or psychiatric hospitals, socket outlets connected to essential circuits should be restricted to those which will be required for supplying essential electrical equipment.

Sterilizing equipment

29. Electrical services including alarms, automatic controls and ancillary circuits which are essential for the safe operation of sterilizing equipment should be supplied from an essential circuit.

Dirty utility rooms

30. Standby power will be required for bedpan washers and macerating machines.

Patient care equipment

31. All special care and patient monitoring equipment must be supplied from essential circuits and given first priority in the event of loss of the normal supply.

Blood banks, etc.

32. Blood banks and other clinical refrigerators are usually equipped with temperature-retaining facilities which will satisfactorily safeguard against power failures of several hours' duration. Nevertheless, it is desirable to supply them from an essential circuit.

Deep-freeze refrigerators and food storage

33. These refrigerators will normally operate within a range of minus 12°C to minus 23°C and be fitted with a temperature alarm device to give warning when the refrigerator temperature approaches the upper safety limit. As the electrical loading is comparatively small they should be supplied from essential circuits as a safeguard against prolonged supply interruptions.

Milk kitchen

34. Refrigerators in food preparation rooms, special care baby units and children's wards should be supplied from essential circuits.

Cold stores

35. These usually operate within a temperature range of 0°C to minus 2°C and are normally provided with sufficient insulation to prevent undue rise in temperature during power failures. It may, however, be desirable to have alternative supply from the standby plant available where this can be conveniently arranged.

Post-mortem room

36. Refrigerating plant for cadaver cabinets should be supplied from an essential circuit.

Kitchens

37. The use of standby electricity supplies will not normally be justified for electric cooking. Where the main kitchen equipment is electrically heated it may be considered advisable to provide alternative non-electric heating facilities as a safeguard against the possibility of power failures.

Boiler plant

38. Essential circuits should be restricted to those which are necessary to enable the plant and its associated alarms, safety controls and ancillary circuits to continue to function in the event of loss of the normal supply. These will include the following:

(i) mechanical stokers or oil burners

(ii) oil tank and supply line heating

(iii) forced and induced draught fans and other mechanical ventilation where this is necessary for the proper operation of the boilers

(iv) boiler feed and condense pumps

(v) heating and flue gas control circuits

(vi) circulating pumps for heating and hot water services

(vii) mechanical fuel and ash-handling equipment where alternative manual facilities are not reasonably practicable

(viii) heat exchange stations.

Diagnostic X-ray machines

39. Fixed X-ray apparatus in the diagnostic rooms will not normally be supplied from essential circuits. Socket outlets on essential circuits should be available to supply portable and mobile machines. In the operation of the mobile machines, allowance may have to be made for the increased mains impedance when the supply is from the standby generator—see Hospital Building Note No. 6: Diagnostic X-ray Department.

Ventilation

40. Standby supply facilities for ventilation purposes will usually apply only to fully mechanically ventilated premises or where mechanical ventilation services are essential for clinical reasons. Where ventilation requirements are met by duplicate plants it will only be necessary for one of the plants to be supplied from the standby source, thus ensuring air supplies of approximately 50 per cent of the normal rate. Change-over switches should be provided to enable either of the plants to be connected to the standby service.

Central piped medical gases, including medical compressed air and medical vacuum installations (*see also Hospital Technical Memorandum No. 22: Piped Medical Gases, Medical Compressed Air and Medical Vacuum Installations*)

41. The associated electrical services of piped medical gases, medical compressed air and medical vacuum installations, including any alarms, safety controls and ancillary circuits should be connected to the essential circuits. It is desirable that motor installations should be so arranged that once they are switched on they will restart automatically following a break in supply. Where remote control is provided, the motor controls should be arranged to remain in the "on" position until the "off" control is operated. Mains isolating switches should of course be located adjacent to the machine for servicing purposes.

Water supplies

42. Where electrically operated pumps are used to maintain essential water supplies (including that for fire-fighting purposes) it will be necessary to make suitable arrangements for the pumps to be connected to the standby supply. Depending on the capacity of the head tanks, it may be possible to use manually-operated changeover switching which will enable the operation of the pumps to be fitted in with other manually-controlled essential loads, thus reducing the maximum demands on the essential part of the installation and the size of the generating plant.

43. Any mains energised alarm circuits associated with water supplies should be so arranged that they are automatically connected to the standby supply in the event of a power failure.

Laundries and other essential supporting services

44. Regional health authorities' plans should provide for the maintenance of about 50 per cent of their normal laundry service. This will involve identifying the laundries which can be kept running on a twenty-four hours a day basis if necessary to provide essential supplies of linen, etc. These laundries could be covered by permanently installed or mobile generators. The advantage of mobile generators is that they can also be used to cover the failure of standby plant at major hospitals. Similar considerations in terms of standby coverage also apply to central catering, sterile supplies and other grouped services.

Sewage disposal

45. Where the pumping of the hospital's sewage is dependent on electricity supplies, facilities should be made for essential equipment to be connected to the standby supply. Where practicable, manually operated change-over switching should be used. The circuits of any electrically operated alarm devices should, however, be so arranged that they will be automatically connected to the standby supply during power failures.

Lifts

46. Where lifts are provided for the movement of patients it is desirable that one bed/passenger lift in each separate section of the hospital should be connected to the essential part of the installation having automatic change-over facilities. These lifts will be regarded as emergency or fireman's lifts and should be suitably indicated by markings at each landing.

47. Where other lifts are supplied from the same machine room as the emergency lift, suitable manually operated switching arrangements should be provided to enable the standby supply to be switched from the emergency lift to each of the other lifts in turn to eliminate the possibility of occupants being trapped in the lifts during power failures. Under normal supply conditions the emergency lifts only will be connected to the essential part of the installation. Figure 1 shows a typical switching and distribution arrangement.

Escalators and paternosters

48. Escalators should not be supplied from essential circuits, but paternoster systems essential to the working of the hospital, i.e. for transportation of documents, samples, meals, etc., will require a standby supply.

Telephone exchanges

49. Telephone exchange equipment and mains energised switchboards should be supplied from essential circuits.

Nurse call and staff call equipment

50. Having regard to the small load required to energise nurse call and staff call equipment it is desirable that these should be connected to essential circuits.

IX. Distribution of essential circuits

New hospital installations

51. With new installations the most suitable arrangement will be to divide the main distribution into essential and non-essential circuits with change-over supply facilities to the busbars feeding the essential circuits. It is important that the mains failure sensing relays for starting the standby generator should be so located as to safeguard against internal sub-main failures in addition to supply failures.

52. For three-phase distribution systems sensing will be required so that a failure of any phase of the supply will automatically bring in the standby generator.

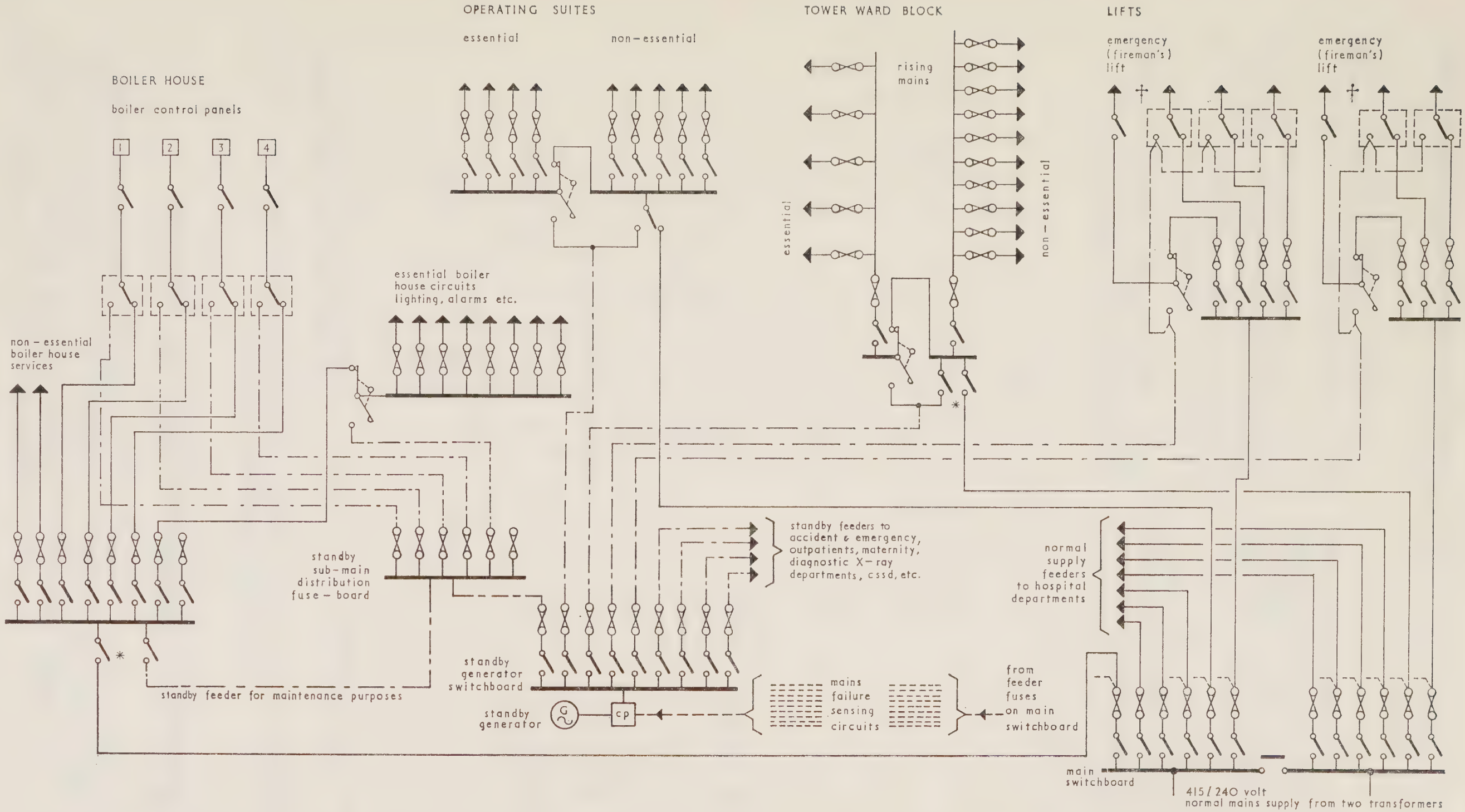
53. Where the same circuit wiring is used for normal and standby supplies, the circuits should be planned, as far as is reasonably practical, to ensure that alternative supply facilities exist in each area served by essential circuits.

54. With larger installations it will usually be necessary to divide the essential circuits between several sub-main feeders, the number depending on the number of circuits and their locations. In these instances where automatic change-over facilities are required it will usually be preferable to provide a separate contactor for each section, together with a separate sensing circuit. Figure 1 shows a typical distribution arrangement.

55. To limit the starting load on the standby generator manual change-over switching should, where practicable, be used with the more heavily loaded equipment, e.g. motors associated with engineering services. The starters controlling these motors will usually be fitted with a no-volt release to ensure that the motor is re-started manually following an interruption of supply.

56. Where several automatic change-over contactors are employed, it is desirable that the change-over timing should be arranged in sequence in order to prevent the load of each contactor being connected to the standby generator at the same time. The switching sequence will be arranged in order of priority of the facilities covered by the different sections.

57. With smaller installations it may be more convenient to supply the most important essential circuits through a single change-over contactor and use manually operated change-over switches for the remainder of the load. With this arrangement the



* Switches interlocked to prevent interconnection of the two supplies.

† Manually operated switches to enable the standby supply to be diverted from the emergency lift to any one other lift in the group. Switches interlocked to permit only one lift in the group to be used in an emergency.

NOTES:

(1) Where economically practicable interconnecting cables should be provided between the sub-distribution centres of hospital departments to provide alternative feeders. Interlocked isolators should be provided to prevent interconnection of the normal and standby supplies.

(2) Single-line representation is used in this diagram for single and 3-phase distribution.

Figure 1. Typical distribution of standby and normal supplies for a district general hospital.

sensing circuit should be connected to the most important section of the installation. Figures 2 and 3 show typical distribution arrangements.

Existing installations

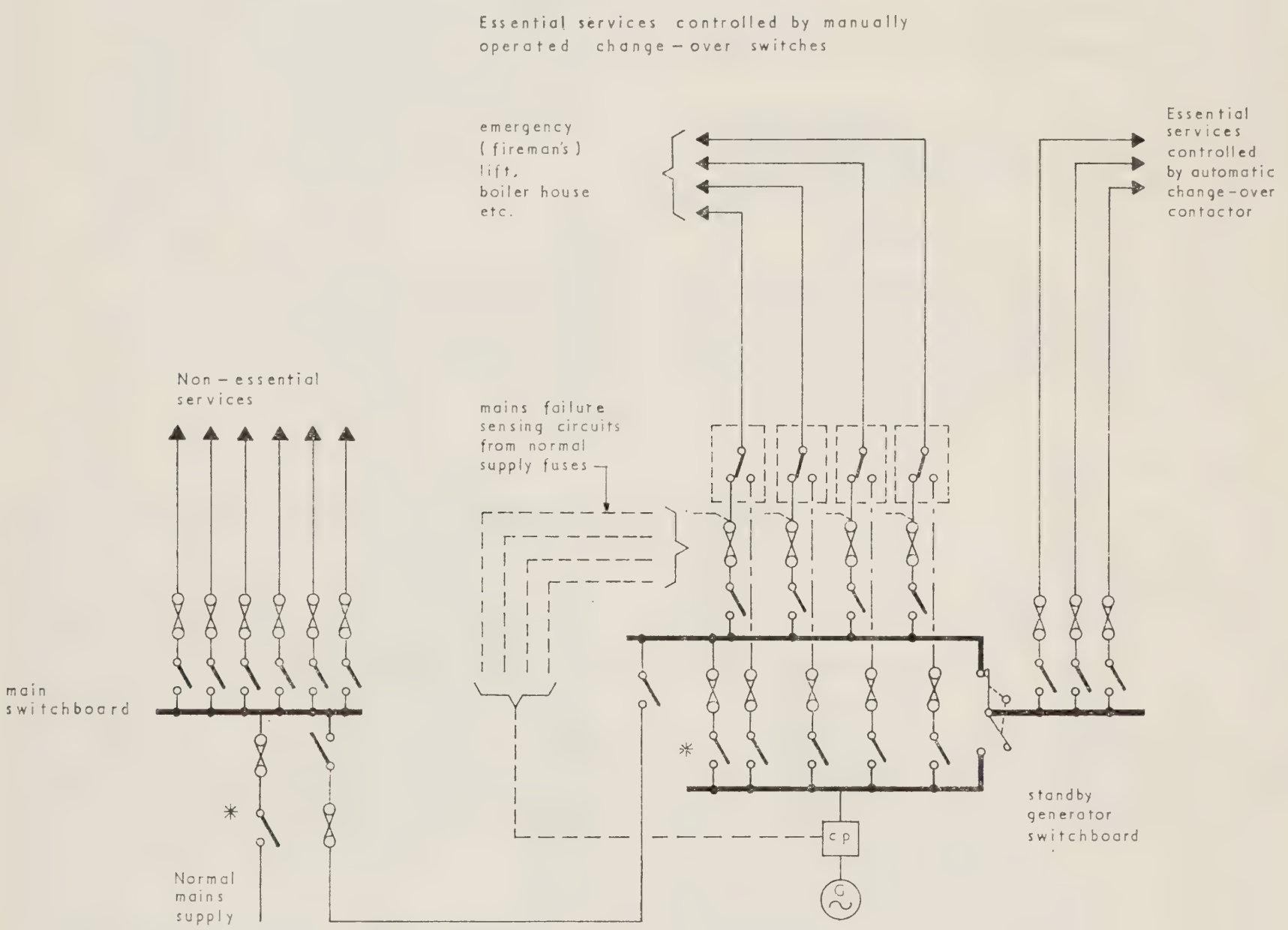
58. Where standby supply facilities are being added to existing installations, the best method of arranging the distribution will vary with the local conditions and will be influenced by the location of the essential loads relative to the main distribution centre and standby plant.

59. In some instances it may be convenient to transfer existing essential lighting and socket outlet sub-circuits to a new distribution board having a new sub-main from the standby supply and a local change-over contactor and sensing circuit (as recommended for new installations).

60. In others it may be preferable to re-arrange existing distribution equipment in order to separate essential and non-essential circuits.

61. Where only limited emergency facilities are to be provided (e.g. safety lighting on escape routes) it will usually be preferable to provide new circuit wiring for the essential points and connect them to the most convenient essential distribution point.

62. The sensing points for change-over contactors should be selected to provide the maximum safeguard against possible internal distribution failures.


Essential services controlled by manually operated change-over switches
emergency (fireman's) lift, boiler house etc.
Essential services controlled by automatic change-over contactor
Non-essential services
mains failure sensing circuits from normal supply fuses
main switchboard
standby generator switchboard
c p
G
Normal mains supply

* Switches interlocked to prevent interconnection of the two supplies.

Single-line representation is used in this diagram for single and 3-phase distribution.

Figure 2. Typical distribution for a smaller-type hospital showing normal and standby supplies with a single change-over contactor and manual change-over switches.

X. Arrangement of emergency lighting circuits

Standby lighting

63. Where the full standard of lighting is required under emergency conditions (*Grade* (*a*)), all circuits will be connected to the essential part of the installation.

64. In areas where a reduced standard of lighting is acceptable (*Grade* (*b*)), certain circuits only will be connected to the essential part of the installation. Whenever economically practicable, the emergency lighting in each area should be arranged on at least

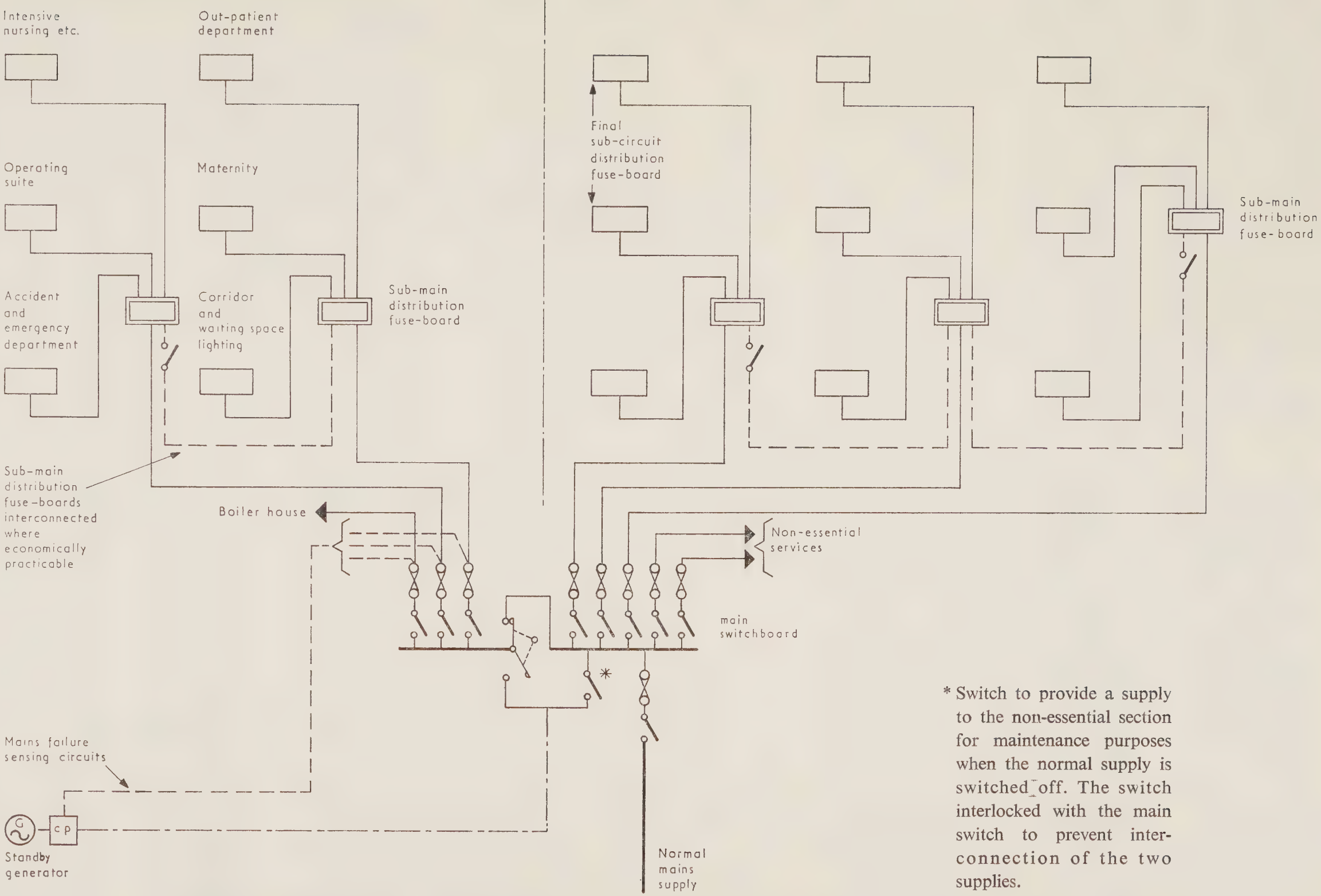

ESSENTIAL DISTRIBUTION
NON-ESSENTIAL DISTRIBUTION
Intensive nursing etc.
Out-patient department
Operating suite
Maternity
Accident and emergency department
Corridor and waiting space lighting
Sub-main distribution fuse-board
Final sub-circuit distribution fuse-board
Sub-main distribution fuse-board
Sub-main distribution fuse-boards interconnected where economically practicable
Boiler house
Non-essential services
main switchboard
*
Mains failure sensing circuits
G
C P
Standby generator
Normal mains supply
* Switch to provide a supply to the non-essential section for maintenance purposes when the normal supply is switched off. The switch interlocked with the main switch to prevent interconnection of the two supplies.
Single-line representation is used in this diagram for single and 3-phase distribution.

Figure 3. Typical distribution with a single change-over contactor for a small hospital.

two separate final sub-circuits to safeguard against local failures.

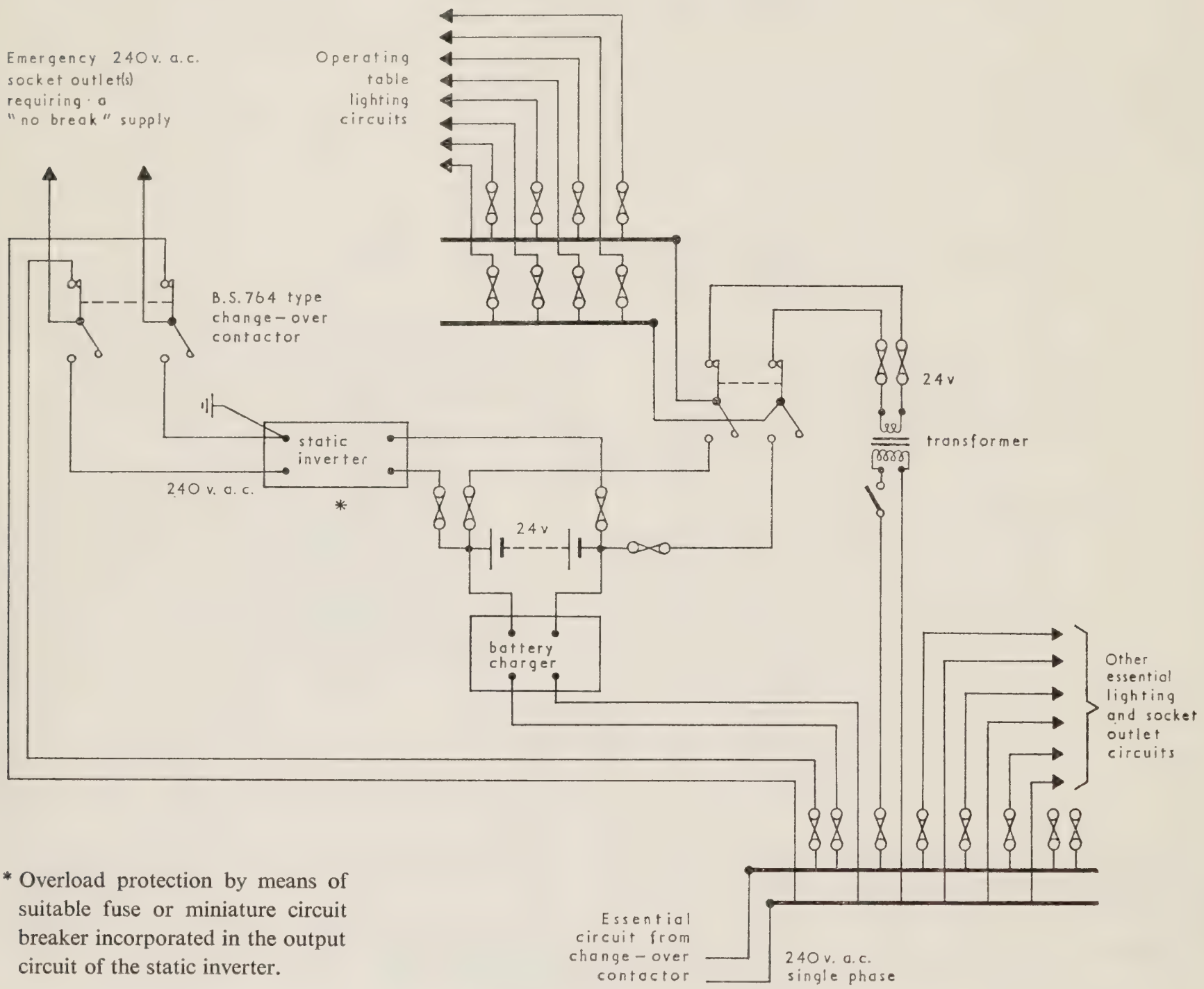
Safety lighting

65. All safety lighting circuits will of course be essential circuits. Where no other standby lighting is being provided, it is important that the safety lighting circuits should be switched with the non-essential lighting circuits serving the area and it may be desirable to link the two circuits, e.g. by the use of double pole switches.

Battery operated emergency lighting

66. Where standby generator supplies are available there will not normally be sufficient justification for providing an additional battery supply for emergency lighting circuits. The short break in supply associated with the normal stationary type of standby generator will be acceptable for most hospital applications. In certain circumstances, however, where a break in supply might be hazardous (e.g. safety lighting on some staircases) the provision of self-contained battery operated emergency lighting fittings will be justified.

67. The provision of a low capacity battery (e.g. one hour capacity) will also be justified as an additional safeguard for operating table lighting in theatres which are used for acute types of major surgery. Figure 4 shows a typical circuit. For other lighting in operating suites a break of a few seconds will be acceptable.



* Overload protection by means of suitable fuse or miniature circuit breaker incorporated in the output circuit of the static inverter.

Figure 4. "No-break" lighting and socket outlet supplies for operating theatres.

XI. Segregation of essential and non-essential circuits

68. Where separate sub-mains are used for essential and non-essential sections of the installation, reasonable steps should be taken to prevent the possibility of a single fault affecting both cables. This may be achieved, for example, by the use of wiring having good fire-resisting properties, armoured cables or wiring enclosed in separate steel conduits or trunking.

69. Mineral insulated metal sheathed (M.I.M.S.) cables have excellent fire-resisting properties, and their use for important essential circuits such as sub-mains may form a convenient means of securing the desired segregation from adjacent non-essential circuits.

70. Complete segregation of all essential sub-circuit wiring may not be justified in all instances. In the most important areas where the essential installation will include a number of sub-circuits, it will be a comparatively simple matter to separate these circuits from the wiring of other non-essential circuits. In other areas where only a small part of the sub-circuit wiring is connected to the essential part of the installation, the additional expense of segregating the essential sub-circuits from the non-essential sub-circuits would not be justified. Safety lighting circuits on main escape routes should, however, always be segregated from other non-essential wiring.

Marking of essential circuits

71. Switchgear and distribution boards which control essential circuits should be conspicuously and indelibly marked to indicate this fact, in addition to the descriptive marking of the circuit controlled.

72. It is recommended that a standard colour marking be used throughout the installation for this purpose. The standard colour marking for electrical services (B.S.1710) is light orange, and it is recommended that a red on light orange be used to indicate essential parts of the installation (e.g. a red spot on a light orange background for switchgear and distribution boards and red on light orange bands for conduits and trunking which house only essential circuits).

XII. Emergency supply equipment

General

73. The type of standby supply required will in most instances be an a.c. supply which has the same rated voltage and frequency as the normal supply. In general a three-phase engine-driven generator will be the most convenient and economical means of providing the supply. Where practicable the use of medium voltage generators will be preferred even where the internal distribution is carried out at high voltage.

74. The type of machine used for standby supply purposes is normally stationary and will be arranged for automatic starting in the event of a failure of the normal supply. There will be a short break in supply of some 10 seconds following loss of the normal supply while the set is run up to its operating speed. Instances where this short break in supply is not acceptable will be very few and applicable to only a small part of the load. In these instances battery operated static inverters, which are virtually instantaneous in action, could be used either alone or as an auxiliary to an engine-driven generator to cover the period of break in supply. No-break sets of the flywheel type and the associated control gear are considerably more expensive than the normal automatic start sets, and the additional expenditure would be justified only in exceptional circumstances.

Engine-driven generators

75. A wide selection of machines is available which have been specially designed for emergency or standby supply purposes.

76. For hospital applications automatic starting will be required, and the ability of the engine to start reliably and rapidly to attain its operating speed will be important.

77. Various types of generators are available and various methods of automatic voltage control are employed. It is important that the generator should be capable of maintaining its terminal voltage within prescribed limits under load conditions which are likely to occur in service. Typical voltage limits are $\pm 2\frac{1}{2}$ per cent of the rated voltage at any load from no load to 10 per cent overload from unity to 0·8 lagging power factor under all ambient conditions. Depending on size it will usually be necessary to allow transient excursions beyond these limits where larger or higher inductive loads are switched.

78. In many instances the differences between types of generator sets are marginal as regards performance and cost. Recent trends have been towards the use of brushless machines (i.e. machines employing static rectification in order to eliminate commutation).

79. Engines are dealt with in greater detail in Section XVI and generators in Section XVII. Figure 5 shows the approximate cost at 1972 level of standby diesel generator sets, complete with equipment for parallel operation, automatic mains failure start, cooling system, generator control board and protective equipment, daily service tank (250 gals. max.), standard silencer and exhaust pipe and delivered to site.

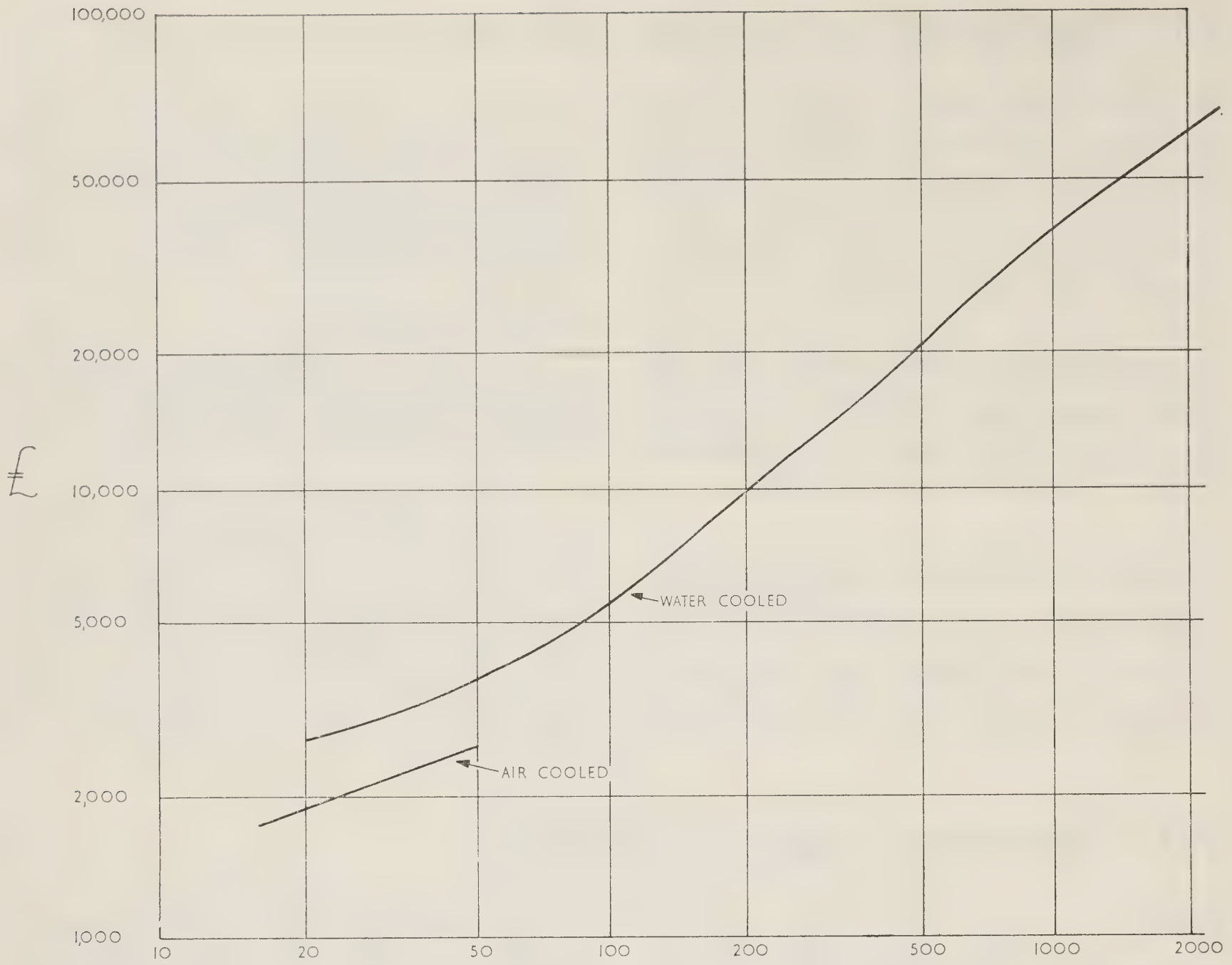


Figure 5. Costs of typical 1500 r.p.m. complete diesel generator sets (1972)

Static inverters

80. The use of battery fed inverters as the only source of standby supply in a hospital will be limited owing to the relatively short period of cover and long period of recovery (i.e. recharging the battery). Their principal use will be as auxiliaries to the engine-driven generator, to cover the period of break in the supply while the generator is being run up to its operating speed, where no-break facilities are essential for a small part of the load.

81. Two types of static inverter have been developed, the transistorised type and the thyristor type. The former has the advantage of producing a roughly sinusoidal wave-form but is mainly restricted to capacities up to 800 watts single-phase. Thyristor type inverters are available with capacities up to several kilowatts but in their simplified form produce a virtually square wave-form which is suitable for motors, tungsten lighting, heating, etc. They may not, however, be suitable for application where the ratio between peak and r.m.s. voltages is important, e.g. thermionic valves and fluorescent lighting. For this type of application additional components (e.g. sine wave filter) will be necessary, and this will increase the cost of the unit. Another disadvantage with any equipment which includes thyristors is that electrical noise is experienced and, if the equipment is to be used near sensitive electronic or counting instruments, it could affect their performance.

82. It is claimed that the semi-conductors used in static inverters do not deteriorate during normal use, although isolated failures have been reported. They can be damaged, however, under certain adverse conditions such as reversal of polarity or the application of excessive peak potentials.

83. In their simplest form an efficiency in excess of 80 per cent is claimed but this will be reduced if a filter is used.

84. The maximum energy that can be passed by a static inverter in the event of a low impedance fault is

limited by the semi-conductor used and may not, under certain conditions, be sufficient to operate the over-current protection devices in the load circuits. The condition is particularly liable to arise where the simplest type of static inverters which have a square wave-form are used, and the failure to clear a fault could seriously affect all the circuits supplied by the inverter. Where a filter is used to improve the wave-form the energy stored in the filter capacitors should be sufficient to increase the short-circuit current for a period long enough to clear suitably rated fuses or circuit breakers.

XIII. Selection of equipment

85. Reliability in service is of prime importance with equipment used for standby supplies. In particular special attention should be given to the reliability of contactors and relays which are used for starting up standby plant and for changing over from normal to standby supply. Experience has shown that more failures are attributable to these components than any other cause.

86. The maximum demand arising, or likely to arise, from essential loads should be carefully studied to ensure that the plant capacity is sufficient to supply the selected loads satisfactorily in the event of a prolonged supply interruption.

87. Compliance with British Standards should be specified in so far as they are applicable and where no nationally accepted standard is available special care should be taken with the specification to ensure that equipment will be satisfactory and reliable for the service required.

XIV. Number of generator sets

88. The most economical and convenient arrangement will be to have a single generator set but for larger installations it may be desirable or necessary to divide the load between two machines.

89. Where more than one engine-driven generator set is provided in the same plant room it will normally be preferable for each unit to supply its own separate portion of the essential load and to provide inter-connection facilities between the units to guard against the possibility of failure of one set. This will also enable a standby supply to be available while one machine is taken out of service for maintenance purposes.

90. Provision for the parallel working of two or more machines would not normally be economical with standby generators unless they are to be used for peak load reduction (see Appendix 2). In this event one set is designated the lead engine and will be used to supply to top priority essential loads, whilst the second will provide power for the lower priority essential loads and act as standby for the first engine. On mains failure both sets start, the lead set immediately taking the top priority loads while the second set is automatically paralleling with the first. When both are operational the load is shared between them and the lower priority loads are manually or automatically connected.

XV. Siting of standby equipment

91. Normally, the most convenient and economic arrangement will be for the standby plant to be centred in a single central room probably adjoining the boiler plant. Such an arrangement will reduce plant installation and plant housing costs and will also simplify and facilitate servicing and routine testing. On dispersed hospital sites the use of a single plant room will entail higher feeder installation costs but the overall cost may be less than that of providing smaller units to suit the load pattern.

92. Wherever practicable the plant should be located well away from patient accommodation and other noise sensitive parts of the hospital.

XVI. Engines for standby generator sets

General

93. Usually diesel engines will be the most satisfactory and most economical prime mover for standby generator sets. Provided that suitable provision is made to ensure that the engine and the engine room are maintained at a suitable temperature, diesel engines generally have reliable starting and running characteristics.

94. For the application under consideration petrol engines have no significant advantage over diesel engines and there is a greater fire risk associated with petrol engines and petrol storage.

95. Gas turbines are available over a wide range for this purpose but have several important disadvantages compared with diesel engines. The most serious

disadvantage is probably the longer time taken to run up to operating speed. Noise is also a problem; in the higher frequency range the noise is more liable to be objectionable. Gas turbines are lighter in weight and more compact but for stationary machines these advantages have less significance.

Type of engine

96. Vertical or vee-type four-stroke naturally aspirated diesel engines are usually preferred for standby supply purposes. Because of limited use, high operating efficiencies are of relatively low importance but turbo-charged engines may be more economical for sets having rated outputs in excess of 60 kW. Engines should be generally in accordance with B.S.649 and suitable for running continuously on fuel that conforms to B.S.2869, Class A.

97. Reliability of starting and running up times tend to be related to the number of cylinders, and it is usually best to select the engine having the most cylinders within the required power range. Figure 6 shows the appropriate range of generator sizes and number of engine cylinders.

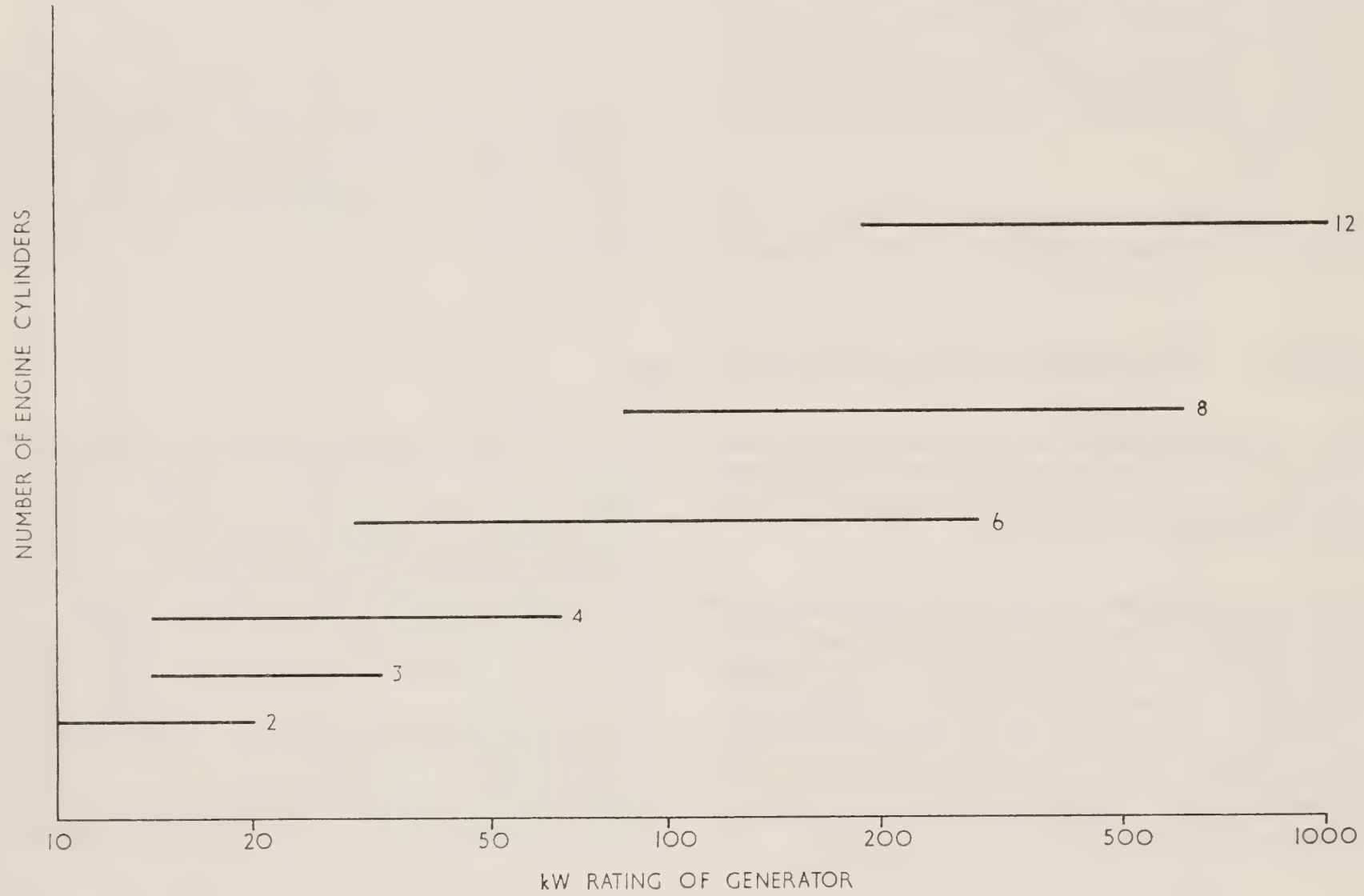


Figure 6. Kilowatt rating of generator sets and number of engine cylinders (1500 r.p.m. engines)

Speed

98. For a 50 Hz supply, machines in the sizes under consideration are available with engine speeds of 1000 r.p.m. for six-pole generators and 1500 r.p.m. for four-pole machines.

99. For a given cylinder capacity the higher engine speed will provide a larger power output and consequently will be smaller and cheaper. A higher rate of wear will be associated with higher speed but this is not considered to be important for sets receiving only limited use.

Power rating

100. Engines should be continuously rated as defined in B.S.649, i.e. after a specified running-up time they should be capable of operating at the rated load for a continuous period of twelve hours which would include a 10 per cent overload for a period not exceeding one hour.

Air-cooled engines

101. For internal stationary type generator sets the use of air-cooled engines is mostly restricted to sizes up to 50 kW. They will be slightly cheaper than water-cooled engines but the cost of saving on the engine could be offset by the need for additional mechanical ventilation in the engine room because of the increased heat gain. They tend to be noisier in operation than water-cooled engines.

102. Air-cooled engines have the ability to start in low temperatures but it is desirable that they should be equipped with a thermostatically controlled electric heater (e.g. an immersion heater in the oil sump) to assist rapid and reliable starting.

Water-cooled engines

103. Water-cooled engines which have a closed circuit radiator cooling system with an engine-driven fan to assist cooling are standard equipment by most

manufacturers for generator sets up to about 250 kW and even larger in some instances. Above 250 kW the radiator would normally be located close to a louvred opening in the engine room wall and have an electrically-operated fan supplied from the generator.

104. The cooling system will usually include a circulating pump and a thermostatically controlled by-pass valve to assist rapid heating up when starting from cold and to control the rate of water flow to the engine. With larger sets it may be necessary to employ a feed and expansion tank for the cooling system. In these circumstances the tank should comply with B.S.417 and be equipped with a suitable level indicator preferably of the magnetic float type.

105. Where the engine room temperature is liable to fall below 10°C a thermostatically controlled immersion heater should be fitted at a low level in the water cooling system and be capable of maintaining the whole of the cooling water at a minimum temperature of 10°C with an ambient temperature of 0°C. The cooling water should have a hardness not exceeding 5 degrees (Clark).

Engine starting

106. Axial type, battery-operated electric starter motors are usually preferred. On larger engines, and in particular those having six or more cylinders, it may be necessary to have two motors arranged to operate simultaneously.

107. Compressed air starting may be necessary with very large diesel generator sets, e.g. 250 kW and above. Compressed air starting, however, is likely to be more expensive than electric starting within the size range for which electric starting is suitable. With compressed air starting it will be necessary to provide duplicate air compressors (one mains-operated and the other having its own prime mover) to allow for the possibility of an initial starting failure.

108. On smaller sets (e.g. up to 50 kW) hand starting facilities should be provided for emergency use.

109. Where there is electric starting there should be means for disconnecting the starter motor automatically after a predetermined time (e.g. ten seconds) if the engine fails to start, to prevent the complete discharge of the battery. An audible warning of failure to start should also be arranged in a part of the premises which is normally manned. In some instances a process timing switch is incorporated in the motor starting circuit and arranged to disconnect the starter motor and repeat the starting attempt at suitable intervals (e.g. eight seconds starting period with three second intervals). If the engine fails to start after the third attempt the starter motor is isolated from the battery and an alarm sounded. Batteries are dealt with under Section XIX.

Engine governor

110. The engine should be fitted with a centrifugal or other type of governor which is capable of complying with the Class A governing requirements of B.S.649. Protection against overspeed must also be provided. Where parallel running is envisaged, however, the normal centrifugal type of engine governor which has a drooping characteristic with load will be inadequate, and hydraulic governors with adjustable droop mechanism and electric speed control are preferred.

Engine failure safeguards

111. Safeguards should be provided to stop the engine automatically by de-energising a solenoid coupled to the stop lever on the fuel injection pump rack and to give visual and/or audible warning in the event of engine overspeed, overheating or loss of oil pressure.

Engine instruments

112. The following instruments are usually provided, mounted on a panel fixed to the engine or incorporated in the main control panel:

(i) oil pressure
(ii) oil thermometer
(iii) cooling water thermometer
(iv) tachometer and service hours counter.

Silencing

113. The exhaust system should be kept as short as possible and should incorporate a flexible section near the engine outlet to reduce the transmission of engine vibration to the remainder of the exhaust system. Bends should have a minimum radius of at least three times the diameter of the pipe.

114. Whenever practicable it is desirable to fit the silencer outside the building to reduce the heating effect. Where a long exhaust system is necessary (e.g. over 7 m), the diameter of the exhaust piping should be increased in order to reduce the possibility of excessive back pressure (e.g. increase to one and a half times the diameter of the engine outlet after the first 3 m). In these instances an expansion joint may be necessary. The exhaust pipework within the building should be provided with suitable insulation to reduce heat emission.

115. Where special silencing is necessary because of the possibility of noise nuisance to adjacent parts of the hospital, it may be convenient to fit an additional silencer (e.g. one of the absorption type in addition to one of the baffle type). Where long exhaust systems or special silencing is necessary, the advice of the engine manufacturer should be sought to ensure that the proposed exhaust systems will not significantly impair engine efficiency.

116. Drain plugs should be fitted in the lower section of the engine exhaust system to remove condensate and thereby reduce corrosion.

117. The position and direction of the exhaust outlet should be selected to reduce the possibility of exhaust gases entering buildings through doors, windows, vents, etc.

Foundation and resilient mountings

118. The overall weight of the engine and the generator should be ascertained from the manufacturer and a suitable concrete foundation provided, capable of supporting the set and withstanding the vibration under working conditions.

119. Usually sets are provided on a common rigid base-plate which will be ready for mounting on suitable anti-vibration mountings fixed to the foundation. Most manufacturers will supply sets of resilient mountings which are suitable for their generator sets. In some instances the base-plate consists of a main frame and a sub-frame with anti-vibration mountings between the two frames. The base-plate height should be sufficient to allow the engine sump to be drained conveniently.

Fuel oil supply

120. Diesel engines for standby generator sets are usually designed for running continuously on fuel that conforms to B.S.2869, Class A.

121. In order to reduce the fire risk, diesel oil fuel stored within the engine room and arranged for gravity feeding should not exceed 150 gals. per engine. In addition, fuel for 200 hours' running for each generator set, and for any generator set which would be hired or borrowed in an emergency, should be readily available from the hospital's own reserve. Where the boiler plant at the hospital operates on 35 sec. oil, the standby generator may be able to share the same fuel oil bulk supply facilities.

122. A hand-operated semi-rotary pump should be provided for transferring fuel oil from the delivery drum or other vessel to the service tank. The pump should be clearly labelled to indicate the type of oil to be used and be fitted with a 4 m length of oil-resisting non-collapsible flexible hose on the suction side. A removable protection cap or cover with retaining chain should be provided on the hose to prevent ingress of dirt when not in use and a removable filter should be incorporated in the oil supply line.

Service tank

123. A service tank is usually arranged as an integral part of the set or is installed at a high level adjacent to the set. Tanks should be constructed generally in accordance with B.S.799, Part 1, and equipped with the following:

(i) filter cap or connection for filling pipe

(ii) vent to atmosphere

(iii) dial type level indicator (with scale clearly marked, i.e. empty, quarter, half, three-quarters and full). The use of gauge glass type level indicators is not recommended

(iv) connections for the injector leak-off return pipe (where necessary)

(v) a drain valve and drain hose connection.

Bulk storage

124. In some instances, e.g. where a standby generator is to be used additionally for peak load reduction (see Appendix 2) it will be necessary to provide suitable bulk storage facilities with an electrically-operated transfer pump located close to the bulk storage tank. Figure 7 shows a typical arrangement.

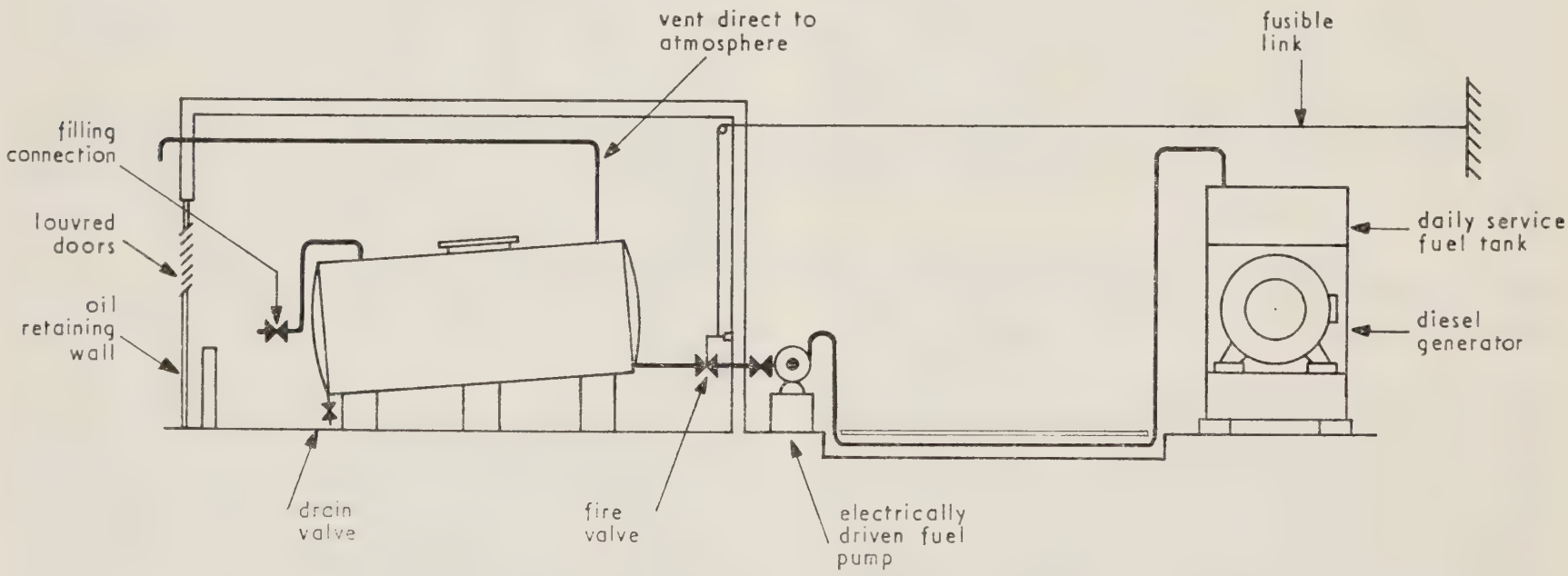


Figure 7. Typical bulk diesel oil storage installation.

125. Tanks located inside the building should be housed in an enclosure of fire-resisting construction and have a catch-pit in accordance with the recommendations of the British Standards Code of Practice (C.P.) 3002. External oil tanks should be located in accordance with the recommendations of C.P.3002. Tanks should incorporate the following facilities:

(i) provision for each tank to be isolated for cleaning and repair

(ii) a vent direct to atmosphere having a cross-sectional area at least equal to the filling pipe

(iii) a visible oil level indicator; where the oil level indicator cannot be seen from the filling point, a float-operated, or other suitable type of over-filling alarm, should be fitted

(iv) tanks, piping and other metalwork associated with the installation should be electrically continuous with the metalwork of the diesel engine set and be earthed in accordance with the requirements of the Regulations for the Electrical Equipment of Buildings issued by the Institution of Electrical Engineers.

XVII. Generators

A.C. synchronous generators

Types of machines

126. Generators can be divided into the following main types although a number of different arrangements are available with each of these:

(i) conventional generators with separate exciters

(ii) generators incorporating inherent automatic voltage regulation

(iii) statically-excited generators

(iv) brushless machines

(v) self-excited generators incorporating engine starting facilities.

Types (i) and (iii) have either rotating armatures or rotating fields. The advantage of a rotating field is that the rotor requires only two slip-rings to carry the excitation current.

Conventional generators

127. Manufacturing experience with conventional generators extends over many years and as a result a high standard of reliability at low cost is assured. The commutator, slip-rings and associated brushgear tend to be the weakest features and need regular servicing. As they have no inherent voltage regulation it is necessary to employ a separate automatic voltage control.

Generator with inherent voltage regulation

128. These are based on the conventional generator but incorporate special windings in the exciter and/or in the generator to obtain automatic voltage regulation over the complete range of output from no load to full load and with varying power factors. This type of machine will be capable of meeting the voltage stability requirements for most hospital applications without the use of a separate automatic voltage regulator. They have the same disadvantage of employing commutation and slip-rings.

Statically-excited generators

129. With this type of machine the excitation current is obtained from a separate static type rectifier and automatic voltage control unit which is supplied from the generator output. The chief advantage of these machines is that commutation is eliminated. The machine relies on residual magnetism to commence generation, and it is important that they are not used under conditions where loss of excitation can occur (e.g. by being allowed to rotate in the reverse direction).

Brushless machines

130. With the brushless machine, d.c. excitation for the rotating field is obtained from a separate rotating armature a.c. generator and semi-conductor rectifiers which are mounted on the same shaft as the field winding. With this arrangement commutation and slip-rings are eliminated. A separate automatic voltage regulator is necessary.

Self-excited generators with engine starting facilities

131. These machines are of a rotating armature type, the armature incorporating a d.c. winding which is used for engine starting and for self-excitation. They are available in small sizes, up to 15 kVA single-phase and 35 kVA three-phase. The machines are intended primarily for use with loads which have a power factor approaching unity, and when used under these conditions can have satisfactory voltage regulation, e.g. $\pm 2\frac{1}{2}$ per cent throughout the load range. With an inductive load, however, the voltage regulation deteriorates considerably.

Choice of generators

132. For the applications under consideration the main choice, depending on size, will be between well tried self-regulating machines, statically-excited generators or brushless machines. Brushless machines have proved satisfactory in use, so much so that unless otherwise specified a brushless machine will be supplied. Machines should comply with B.S.4999.

Voltage regulation limits

133. The steady static voltage should be maintained within $\pm 2\frac{1}{2}$ per cent of the rated voltage at any load from no load to 10 per cent overload from unity to 0·8 lagging power factor under all ambient conditions. After a change of load the voltage should not vary by more than ± 15 per cent of the rated voltage and should return to within ± 3 per cent within three seconds and to within $\pm 2\frac{1}{2}$ per cent within fifteen seconds. On starting, the voltage overshoot should not exceed 15 per cent and should return to within 3 per cent in not more than three seconds. Provision should be made for adjusting the generator voltage within ± 5 per cent.

Rated output

134. The generator should be capable of supplying its rated output continuously at a power factor of 0·8 lagging.

Wave-form

135. The voltage wave-form of the generator should be a sine wave shape within the permitted limits of B.S.4999. This requirement should apply to generators regardless of size.

Terminals

136. The main auxiliary and earthing terminals should be adequate in size for the current to be carried and properly and securely mounted and protected. Means should be provided for preventing the terminals from working loose after connections have been made. Terminal boxes should be of steel construction suitable for the reception of steel wire or armoured P.V.C. cables. Terminal markings should comply with B.S.822, Part 6.

Wiring

137. Wiring between components mounted on the generator set frame should have adequate protection against oil and mechanical damage, e.g. consist of M.I.M.S. cable or wiring enclosed in screwed conduit. Flexible metallic conduit or other flexible types of wiring which provide similar protection against mechanical damage should be used between rigid components and those which are liable to be subjected to vibration whilst the set is in use.

XVIII. Controls, change-over contactors, relays etc.

Controls

138. With small and medium sized diesel generator sets it is usual to mount the control panel on the main frame of the set. With large sets a floor-standing control cubicle is necessary.

139. Where control panels are fixed to the main frame, resilient mountings should be used to reduce vibration.

140. Side and rear panels should be provided as necessary to ensure that all live conductors are fully shrouded against accidental contact. These panels should be hinged or arranged for easy removal to facilitate servicing.

141. All covers, both internal and external, which are removable to allow access to components which operate at potentials exceeding 250 volts should be marked 'DANGER . . . . . VOLTS'. Danger notices should comply with B.S.2771.

142. It should be specified whether overhead or underground cable runs will be used for the wiring connections to the control panel and suitable entry provision made for the trunking or conduits enclosing this wiring.

Change-over contactors

143. The provision of satisfactory and reliable change-over contactors and relays is a very important part of the standby supply equipment. Compliance with British Standards or other appropriate specifications (e.g. the Post Office specification for relays) should be specified where applicable. Where no nationally accepted specification is available for specific items, hospital authorities should require that such items should meet the general test requirements applicable to similar items which have nationally accepted standards.

144. Larger sizes of change-over contactors tend to be less reliable, and it is recommended that contactors which have a current rating in excess of 100 amps should not be used for standby supply purposes. Where loads exceed this value it is preferable to divide the load between two or more contactors.

145. Change-over contactors should be housed in dust-proof enclosures.

Types of change-over contactors

146. B.S.764 covers the manufacture of double-pole change-over contactors up to 100 amps. The contactors are primarily intended for use with non-inductive loads but in general they should be satisfactory for single-phase loads such as are likely to be found in hospital operating departments, etc.

147. An important feature of contactors which comply with B.S.764 is that the contacts are held closed to the normal position by electro-magnets which are energised from the normal supply, and this force alone prevents the contacts from closing to the emergency position under the action of gravity and/or springs.

148. This type of contactor will operate rapidly and fail to safety, i.e. it will close to the emergency position under any foreseeable fault condition affecting the supply or the contactor itself. This is a very desirable feature for change-over contactors for emergency supply uses.

149. Rapid action is an advantage with battery or static inverter supplies but is a disadvantage with standby generators because the load is switched on to the generator before it has reached its operating speed. With diesel generator supplies therefore contactors complying with B.S.764 should be used only for a comparatively small part of the load, the bulk of the load being controlled by contactors incorporating a suitable time delay or being hand switched after the set has run up to its operating speed.

Change-over contactors for standby generator sets

150. Automatic change-over contactors used with standby generators usually employ two separate contactors with their respective electro-magnets energised by the normal and standby supplies in conjunction with a time delay relay. They should incorporate interlocks to prevent the possibility of the two sources of supply being connected together.

151. The contactors should comply generally with B.S.775, Class UR (uninterrupted rating), category AC3. The contactor should be capable of satisfying the making and breaking capacity test with inductive load having a power factor of 0·8 lagging.

Change-over switching and timing

152. Although it is important that the standby supply is rapidly available following an interruption of the

normal supply, it is also important to prevent unnecessary operation of the standby supply equipment due to transient changes in voltage such as are liable to occur under normal supply conditions, e.g. due to load switching on the supply system.

153. The choice of low operating voltage for the voltage sensitive relay controlling the change-over contactor will not in itself be a complete safeguard against this possibility, since transient falls in voltage may exceed the minimum operating voltage of the relay. It will accordingly be necessary to introduce a short time delay to prevent this possibility.

154. The mains sensing relays should have adjustable voltage settings within the range of 75 per cent to 95 per cent and be set normally at 85 per cent. The time delay devices should be adjustable up to thirty seconds and set normally at one second. The relays should be designed to operate on the occurrence of sustained low voltage or loss of voltage on any one or more phases of the supply.

Reconnection of essential circuits to normal supply

155. With satisfactory standby supply arrangements the need for rapid automatic reconnection of the essential circuits to the normal supply or the restoration of supply is not important. Automatic reconnection can be achieved by the use of a suitable contactor and time delay relay but it is a further complication of the control equipment. Manual reinstatement to normal working is satisfactory in many instances and is practicable where suitable manpower is available. The use of the manual switching will also ensure that the standby supply generator is checked over whilst it is connected to the load, as distinct from routine runs which may have to be made with the generator on open circuit.

156. Where automatic reconnection to the normal supply is considered to be necessary, a time delay should be introduced to enable the supply to be properly established before essential circuits are connected. A minimum operating voltage equal to 90 per cent of the rated voltage with a time delay of two minutes following the reinstatement of the supply will be satisfactory in most instances.

Relays

157. Normally the relays will be used infrequently and this increases the possibility of failure; consequently it is extremely important that relays which are necessary for the proper functioning of the equipment are reliable. Relays should be of the plug-in type enclosed in dust-tight covers; they should have high grade contacts throughout and comply generally with an appropriate Post Office specification.

158. The control panel wiring should be carried out using P.V.C. insulated cables complying with B.S.6231. The minimum size of conductor should be 1·5 mm^2 for rigid cable and 0·75 mm^2 for flexible cable. All wiring should be adequately supported and protected. Particular care should be taken where cables are subject to movement, such as hinged doors. Wiring at extra low voltage must be segregated from that of mains voltage. Appropriate colours of insulation should be used for the different circuits and phases and numbered identification sleeves securely fixed to the cables to correspond with the diagram of connections.

Components on control panel

159. The components required on the control panel will vary with the size of the generator set and the type of distribution used. The following represents a typical list for a single change-over contactor arrangement:

(i) interlocked change-over contactor
(ii) time delay mains failure relay for change-over contactor
(iii) voltage sensitive relay for change-over contactor
(iv) generator over-current lock off relay controlling change-over contactor
(v) time delay relay for automatic mains reinstatement
(vi) by-pass switching and mains isolator for isolating control panel for servicing purposes
(vii) push button control for motor starter
(viii) push button for stopping the engine
(ix) starter sequence timer and switch
(x) mains failure simulating switch (push button arranged with spring return to the "on" position)
(xi) failure to start relay with associated audible and visual warning
(xii) oil pressure gauge with low pressure warning light
(xiii) high engine temperature relay with audible and visual warning
(xiv) generator voltmeter with phase-selection switching
(xv) ammeter with phase-selection switching
(xvi) frequency meter
(xvii) battery charger
(xviii) isolator and visual indicator
(xix) battery ammeter
(xx) battery reverse current cut-out (where necessary)
(xxi) indicator lamp—mains on load
(xxii) indicator lamp—generator on load
(xxiii) auxiliary fuses protecting voltmeters
(xxiv) automatic voltage regulator (where required)
(xxv) hand-operated pre-set voltage control (where required)
(xxvi) engine heater switch with indicator lamp (where required)
(xxvii) kW meter (3-phase, 4 wire).

Remote controls and indicators

(i) push button for starting engine
(ii) push button for stopping engine
(iii) warning against failure to start
(iv) generator on load indicator.

NOTE:

Where local change-over contactors are provided the change-over contactor and associated components on the control panel will be omitted and other provisions made for protecting the generator against excessive overload, e.g. circuit breaker or HRC type fuses.

Warning notices

160. A conspicuous notice should be provided in a prominent position on each side of the set to read as follows:

DANGER

THIS MACHINE IS AUTOMATICALLY CONTROLLED.
DO NOT WORK ON IT UNTIL STARTING EQUIPMENT IS ISOLATED OR DISCONNECTED.

161. A notice should also be provided near the by-pass switch warning against leaving the generator switched off.

162. Figures 8 and 9 show typical schematic diagrams of diesel generator controls.

XIX. Batteries for emergency supply purposes

General

163. Batteries for emergency lighting may be of an alkaline or lead-acid type but for diesel engine starting the lead-acid type is preferred. Batteries should be of heavy duty high performance quality and suitable for trickle and rapid charging after use.

164. The recommended voltage for emergency lighting purposes and for diesel engine starting is 24 v.

Emergency lighting

165. Batteries which are the only source of emergency power should have sufficient capacity to supply the connected load continuously for a period of three hours. Batteries which will work in conjunction with a diesel generator set to provide no-break facilities during the period that the set is being run up to its operating speed should be rated for a half-hour continuous discharge period.

Starter batteries

166. The capacity of the battery required will depend on the size of the engine and the number of cylinders. Typical battery sizes are given in the following table:

kW rating	*Ampere-hour capacity of 24 v battery*
Up to 20	65– 75
20– 40	75– 85
40–100	85–110
100–150	110–140
150–200	140–190
200–300	190–250

NOTE:

These battery sizes are applicable to naturally-aspirated engines running at 1500 r.p.m. For 1000 r.p.m. machines of the same output a battery of approximately 50 per cent larger capacity will be required.

167. Starter batteries should be located as close to the engine as is practicable in order to minimise a voltage drop in the leads.

Battery charging

168. The battery charging facilities should be capable of maintaining the battery in a healthy state during the long periods of disuse that could occur, and of automatically recharging the battery in the shortest practicable time, consistent with battery welfare, following periods of use. This is best achieved by a static type of battery charger employing semi-conductors which monitor the battery voltage and control the charging cycle to suit the state of charge of the battery.

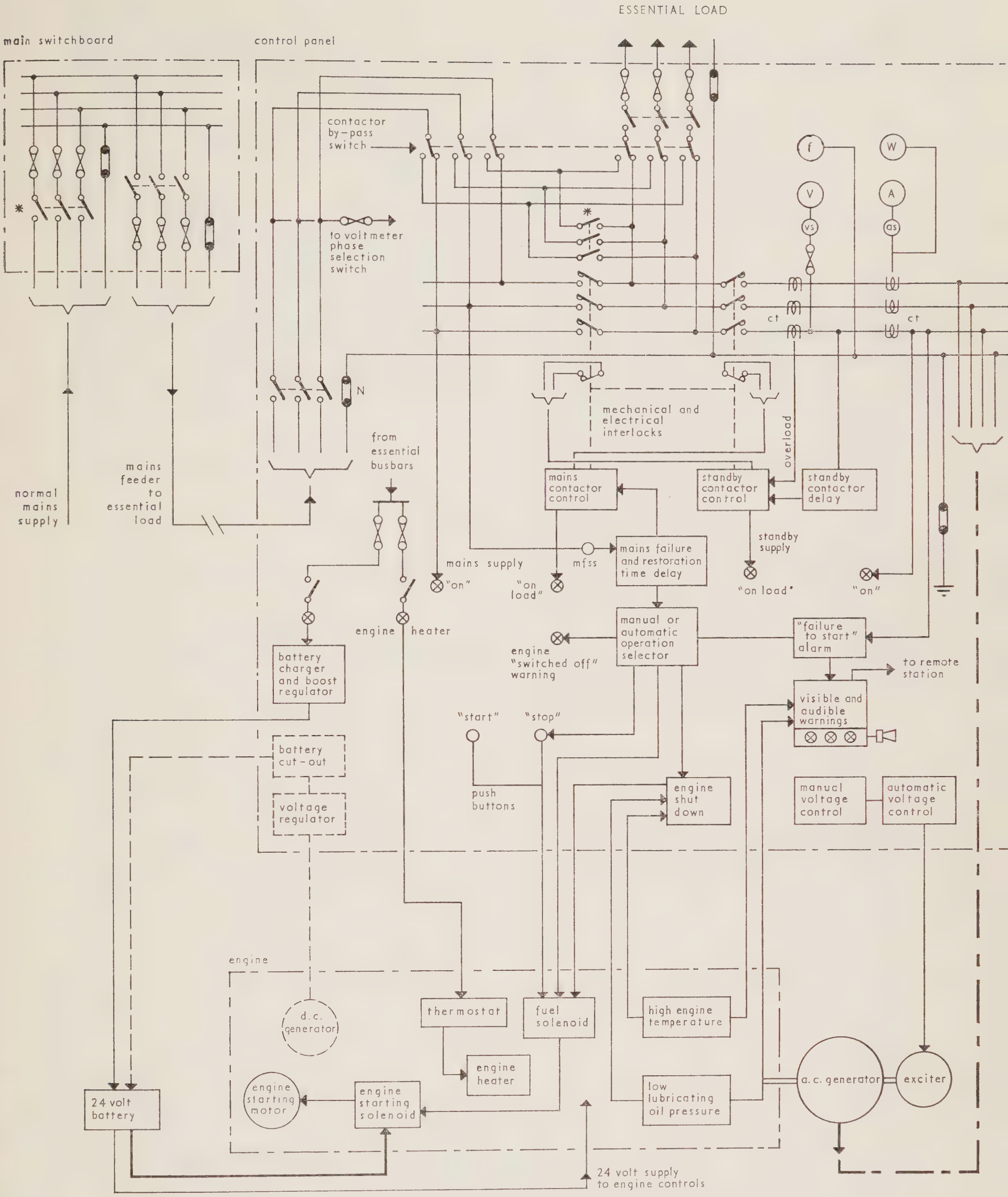
169. The use of manually controlled battery charging is not recommended.

XX. Testing and handing-over procedure

Works testing

170. Generator sets should be tested as a complete unit (i.e. with associated control equipment) for output and performance in accordance with the requirements of B.S.649, B.S.2613 and B.S.4999 as appropriate. The test will include:

(i) series of test starts and checks on ability to take up the load within the specified time
(ii) check that speed variation is within specified limits
(iii) six-hour full load run and fuel consumption check
(iv) one hour 10 per cent overload test
(v) temperature rise
(vi) voltage regulation
(vii) high voltage test
(viii) efficiency test or, alternatively, manufacturer's test certificate may be accepted
(ix) check that all warning and safety cut-out features are functioning correctly.



* switches interlocked to prevent interconnection of the two supplies.

c.t. current transformer.

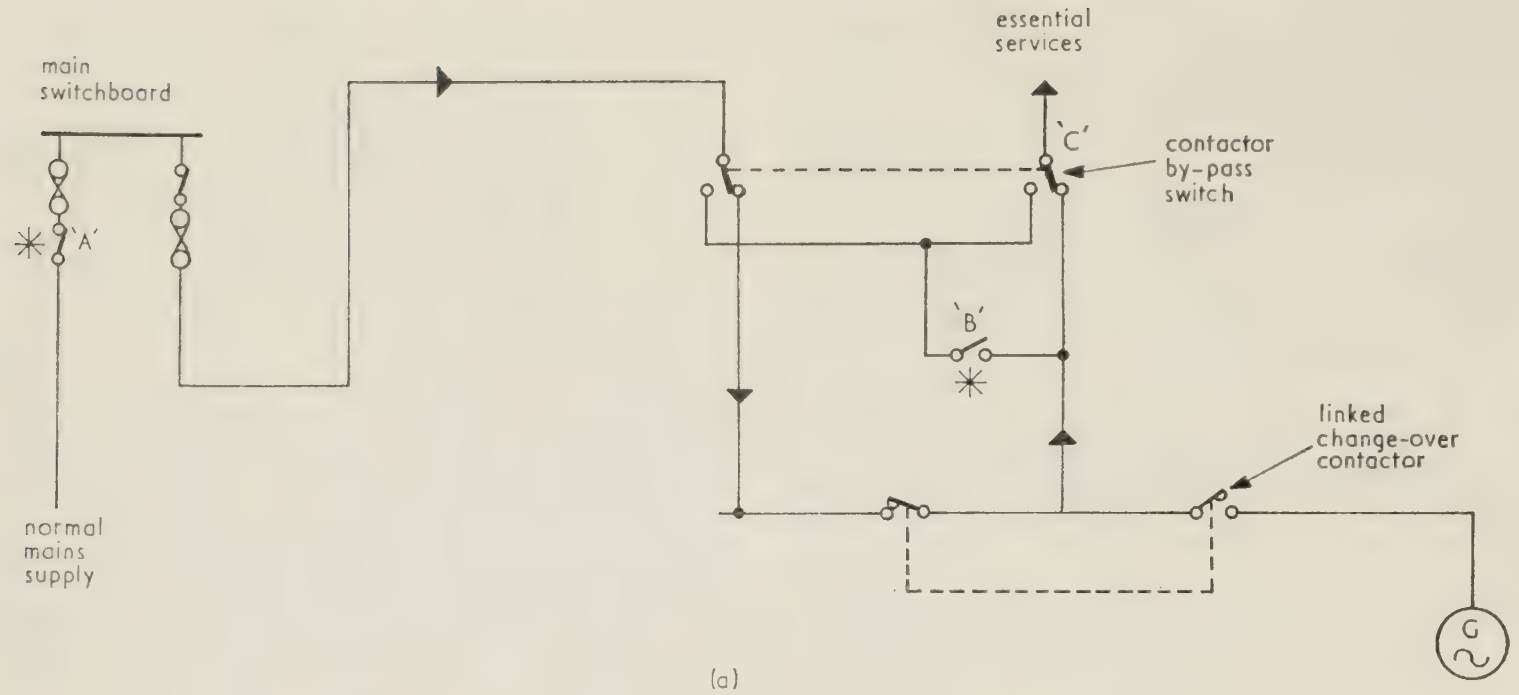
mfss. mains failure simulation switch.

(vs) voltmeter phase selection switch.

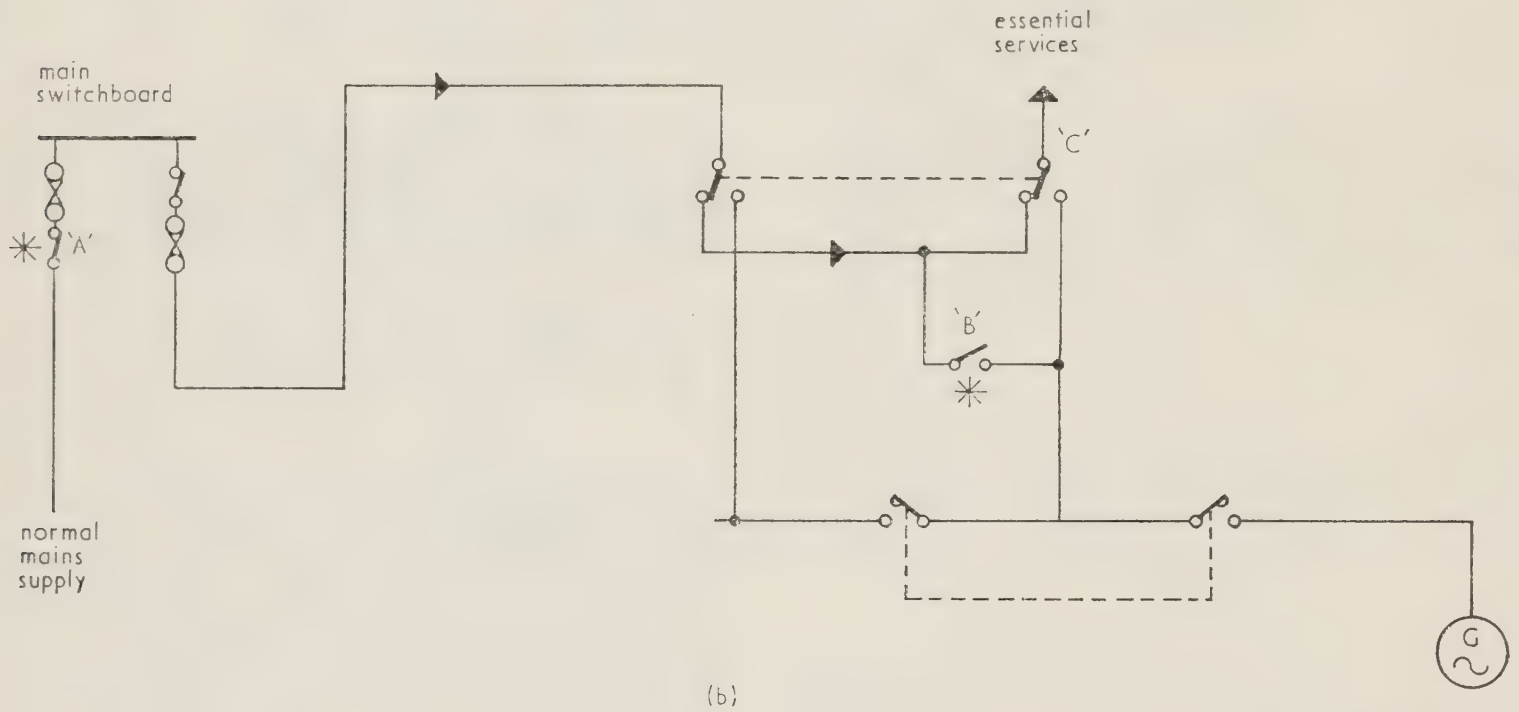
(as) ammeter phase selection switch.

NOTE: The earthing and interconnection of the generator neutral v the mains neutral will require the agreement of the Area Electri Board. The neutral is shown solidly earthed with bolted links in circ in some cases, however, a 4-pole change-over arrangement may required.

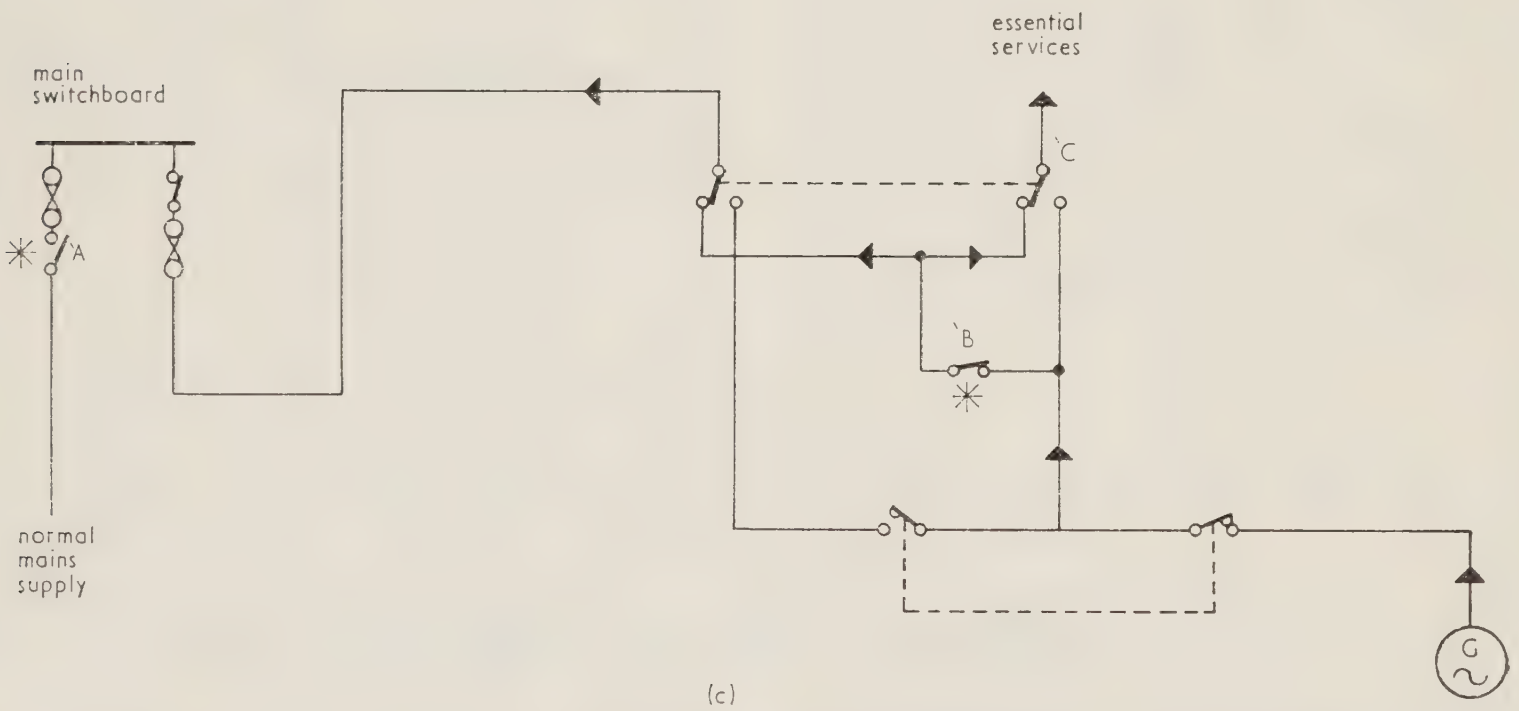
Figure 8. Standby diesel generator controls for automatic mains failure operation.



(a)



(b)



(c)

NOTE: Single-line representation is used in these diagrams for a 3-phase system.

Figure 9. Maintenance switching arrangements for the diesel generator controls shown in Figure 12.

(*a*) Normal operation.
(*b*) Change-over contactor by-passed for maintenance on contactor and standby equipment.
(*c*) Standby generator used to supply the essential load and to provide a limited supply to the main switchboard at time of mains shutdown for maintenance purposes. Switches marked thus * are interlocked to prevent interconnection of the two supplies.
(Switch "B" must be operated before switch "C".)

Final test

171. Upon completion there should be a thorough inspection and testing of the installation to ensure that it conforms with the specification.

Handing-over procedure

172. The handing-over procedure outlined in Hospital Technical Memorandum No. 7: Electrical Services—Supply and Distribution, should be followed.

XXI. Spares, tools and instructions

Spares

173. Modern diesel engines are capable of extensive use between overhauls. Running times between major overhauls will vary considerably with the type of use. Typical running times between top overhauls are 2,000 hours for machines used only for standby purposes and 8,000 hours for machines used for peak load reduction. Generators will be capable of operating for several years before a major overhaul is necessary and, in these circumstances, only limited spares need be kept at the hospital.

The following spares list is suggested:

(i) one complete set of gaskets, special packings, etc.

(ii) one set of renewable parts for oil fuel and air inlet filters

(iii) two complete fuel injectors

(iv) one complete set of brushes for generator and starter motor

(v) one type of each belt (where provided)

(vi) one flexible insertion for each type of coupling

(vii) one automatic voltage regulator

(viii) one set of rotating diodes for brushless machine

(ix) one set of engine control relays.

Tools

174. A complete set of high quality spanners and special tools which are necessary for maintenance of the plant should be held.

Instructions

175. Instructions for starting, stopping, correct operation and routine testing should be supplied with each set. General guidance on maintenance is given in Hospital Technical Memorandum No. 13: Planned Preventive Maintenance, and servicing should be based on that document (which is to be incorporated in "ESTMANCODE") and on the appropriate servicing instructions issued by the manufacturers.

Maintenance reports

176. Routine servicing operations should be scheduled and a log kept of all work which is carried out, including details of any components or parts which are renewed and a brief note of any defects or failures. The log should include details of running the set (e.g. test runs caused by mains failure or scheduled supply interruptions and runs for maintenance purposes). The log should also include the weekly test of the specific gravity of the starter battery electrolyte.

Test runs

177. Test runs should be made at least every two weeks, without load, for a period of thirty minutes, and wherever practicable it is recommended that the set is run on load for a period of two hours once a month. Test runs should be initiated by operating the mains failure simulation switch.

Appendix 1

Engine rooms

Siting

1. Where practicable engine rooms should be located at ground level; basement sites should be avoided because of restricted access for fire-fighting purposes and the possibility of flooding. It is also necessary to consider the fire risk to other parts of the hospital and the effect of the noise on the hospital.

Access

2. The engine room should be sited so that there is convenient access from a good road to allow easy approach for fire brigade appliances, maintenance vehicles, etc.

Layout

3. The layout should be such as to allow adequate space for servicing. Figures 10 and 11 are intended to show typical arrangements for engine rooms containing one and two diesel generator sets respectively.

Construction

4. The engine room and any associated room used for oil storage should be of fire-resisting construction, i.e. as provided by 115 mm brick, 100 mm reinforced concrete slab minimum or equivalent.

5. The main access doors should allow sufficient clearance for the passage of the engine and generator. Doorway openings to other parts of the premises should be fitted with fire-resisting self-closing doors (minimum half-hour resistance). Doors should always open in the direction of the means of escape.

6. Floors should have a suitable non-slip and oil-resisting finish.

7. Internal walls should have a finish which, as far as possible, resists the build-up of dirt and can be easily and effectively cleaned.

Ventilation

8. Adequate ventilation is important to ensure a satisfactory air supply for the engine and to prevent undue temperature rise in the engine room.

9. An air outlet, which opens direct to the outer air, should have an effective area at least equal to that of the radiator of the engine cooling system and be so positioned in the wall that it is in direct line with the air flow through the radiator. With larger sets, where the radiator is mounted on the engine bedplate, it is preferable to provide trunking having a cross-sectional area at least equal to that of the radiator, between the radiator and the openings. This arrangement will improve the effectiveness of the engine cooling and reduce heat gain in the engine room. Where special ventilation is not used, outlet vents should be located at a high level.

10. With air-cooled engines the outlet ventilation should have an area of at least double that of the engine hot air outlet.

11. Suitable inlet ventilation openings should also be provided at a low level in the engine room and have a total effective area at least 50 per cent greater than that of the outlet vents to allow for combustion air.

12. Ventilation openings should be fitted with louvres or other suitable weather protection and be adjustable to enable them to be closed when the engine is not in use and so reduce the heat losses. With larger sets it may be considered necessary to have thermostatically controlled inlet and outlet vents, e.g. using motorised louvres controlled by a room thermostat with limit switches at the end of the travel in each direction. With automatic-start generator sets all ventilation louvres should be either permanently open or be motorised and move to the open position automatically on start-up of the engine.

Height of engine room

13. Standard room heights will be satisfactory for small engine generator sets (e.g. up to 50 kW capacity) but with larger sets it is desirable to increase the ceiling height in order to lower the ambient temperature conditions in the working plane. The advice of the makers should be sought.

Heating

14. Thermostatically controlled heating should be capable of preventing the temperature in the engine room falling below 10°C. Where electric heating is used, the heater should be permanently installed and be of a totally enclosed low temperature type.

Lighting

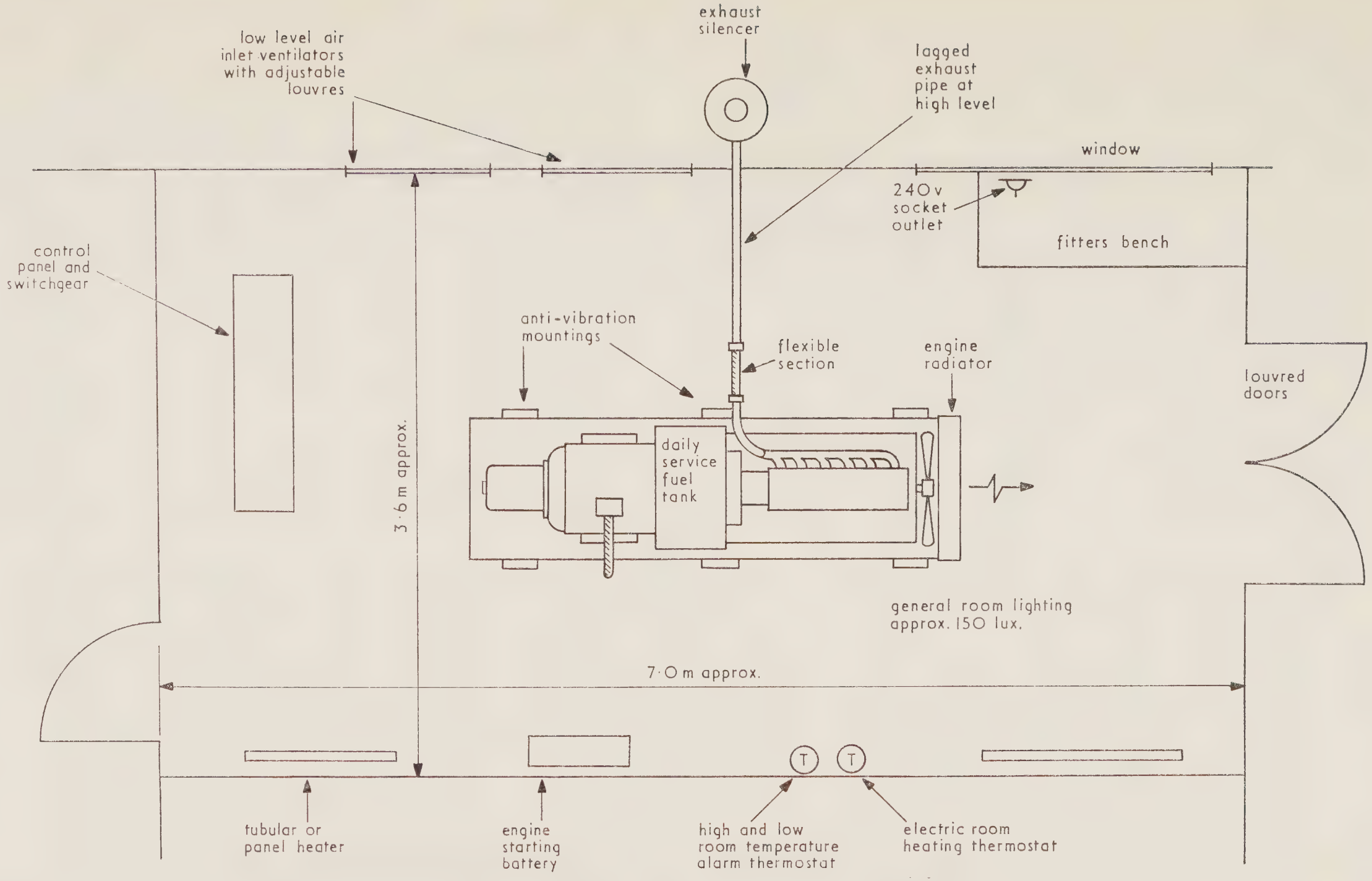
15. An adequate level of illumination should be provided (e.g. a minimum of 150 lux) in the working area with good illumination to the front of the control panel. Discharge lighting should not be used where there is the possibility of rotating machinery appearing to be stationary because of stroboscopic effect.

Socket outlets

16. 13 amp socket outlets should be provided to allow the convenient use of portable tools and to supply the battery charging unit. The provision of extra low voltage socket outlets is not recommended; a more satisfactory method of supplying hand lamps is to use a plug-in type step-down transformer specially designed for the purpose.

Fire extinguishing equipment

17. Advice on the fire extinguishing equipment should be sought from the Chief Fire Officer of the area. Attention should be paid to the contents of Hospital Technical Memorandum No. 16 (Revised): Fire Precautions.

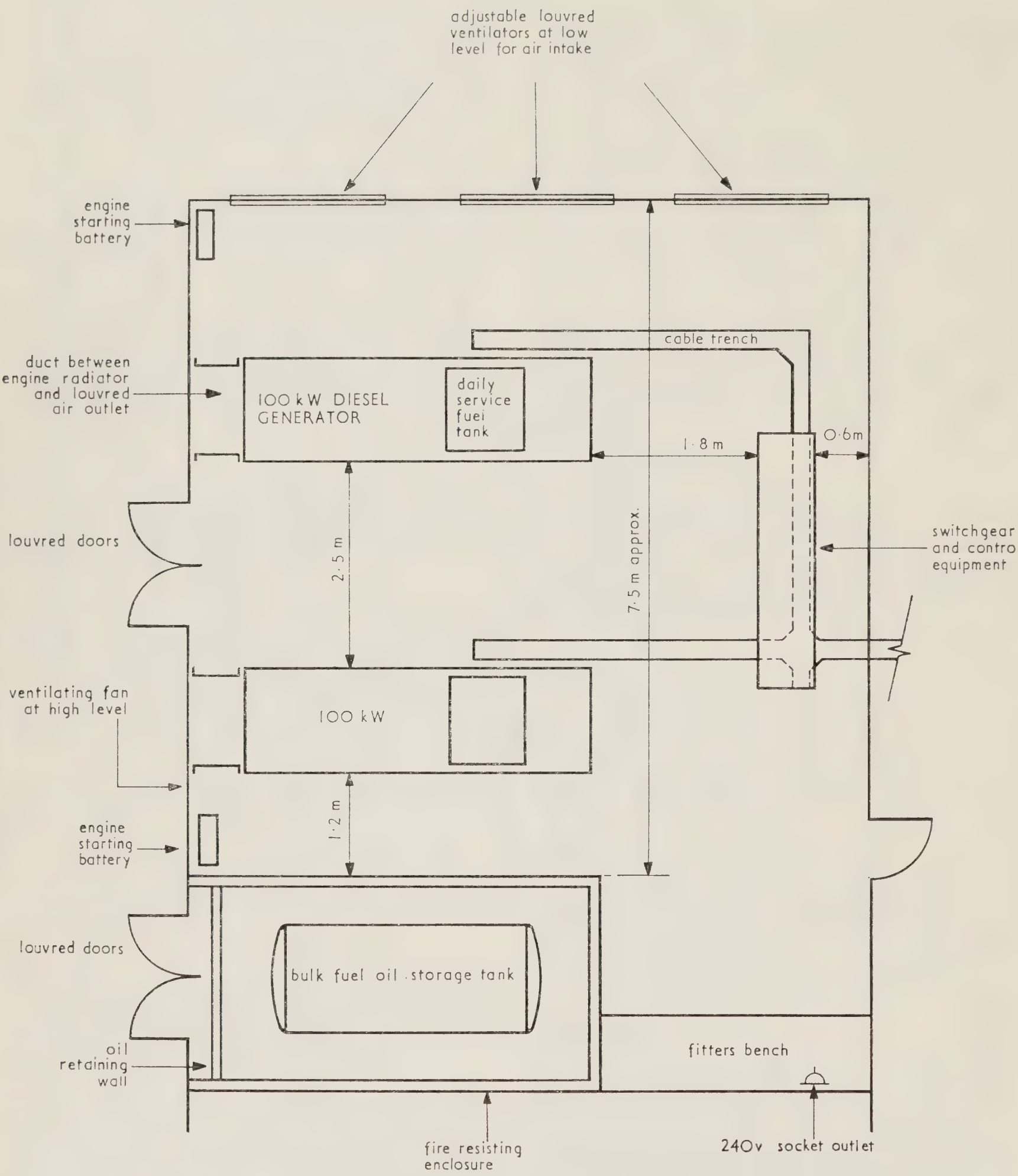


NOTE: Typical operating values for engine room temperature alarms:

high temperature	35°C
low temperature	7°C

Remote indicator lamps and audible alarm positioned at a permanently manned station, for example in the boiler house.

Figure 10. Typical diesel generator installation (100 kW).



NOTE: layout not to scale.

Figure 11. Layout for two 100 kW diesel generator sets.

Appendix 2

Use of generators for peak load reduction

General

1. Engine-driven generators which are provided as a safeguard against possible loss of the normal supply will get limited use for this purpose, and the possibility of using the plant for peak load reduction (peak-lopping) should be investigated. It is important of course that other uses of the plant must be secondary to the main purpose of supplying essential services in the event of power interruptions, and other uses must not impair its effectiveness for standby purposes.

2. Peak-lopping normally pre-supposes that the generating plant is capable of and permitted to run in parallel with the public supply. If parallel operation is not catered for in the generating equipment purchased, peak-lopping of a type can then only be carried out by supplying isolated circuits independently.

3. Factors which will influence the decision whether or not peak-lopping should be undertaken are:

(i) agreement with the Area Electricity Board
(ii) electricity tariff charges
(iii) daily load pattern and annual load factor
(iv) cost per unit generated
(v) size of generating plant.

These points are discussed below.

Area electricity board agreement

4. Each Area Electricity Board decides its own policy and conditions governing the use of private generating plant in parallel with its own supply. Thus it is always essential to carry out close consultation with the electricity board before embarking on any detailed investigations. The essential technical requirements, however, will be:

(i) parallel operation should not jeopardise either the public supply or the private system, nor should it introduce hazards to the electricity board's system
(ii) normally a reverse power relay is fitted to the supply switch from the electricity board so as to prevent the export of power
(iii) the generator should operate at a power factor not greater than that of the normal load of the site, so as to minimise the reactive energy drawn from or supplied to the electricity board's system
(iv) the neutral earthing must conform to the Electricity Supply Regulations 1937. For h.v. and l.v. generation only the supply system is earthed at the neutral point for parallel operation. This means that a neutral earthing switch should be installed which is open when the set is in parallel with the public supply and closed when generating independently
(v) there must be competent personnel always in attendance at the generating plant to take instructions from the electricity board's control engineers.

5. In general, electricity boards do not encourage small (less than 200/300 kW) peak-lopping schemes in parallel because of the danger of incompatible supplies. Electricity boards are unlikely to agree to peak-lopping in excess of 25 per cent of the total demand.

Electricity tariffs

6. Each electricity board has its own series of charges for electricity, and most tariffs which are applicable to hospitals include a maximum demand charge based on twice the maximum number of units supplied during any thirty consecutive minutes within a defined period.

7. The tariffs most satisfactory for peak-lopping schemes have a monthly maximum demand rate which varies from a maximum in the winter to a minimum in the seven summer months. With this tariff, generating plant need only operate up to 2,000 hours per year from 1 November until 31 March.

8. For peak-lopping schemes the electricity boards will normally make an additional charge for holding available the necessary standby capacity. This standby supply is for use only in the event of breakdown and/or maintenance of all or part of the private generating plant. The charge is normally expressed in a special tariff as a service charge, negotiated with the consumer and is currently (1972) in the region of £5 per kVA of reserved capacity. Service charges will have an important influence on the overall economics of peak load reduction.

Daily load and annual maximum demand pattern

9. When investigating the possibilities of on-site generation for peak load reduction it is necessary to obtain, in as much detail as possible, the daily, monthly and annual profile of the hospital's electrical demand. For existing hospitals the electricity bills will provide the most useful sources of information; for projected hospitals outline estimates should be used. The economic feasibility of any peak-lopping scheme will be largely dependent on the shape of the daily and annual load curves. Peak-lopping will not be worth-while investigating unless the hospital has a peaky load shape which occurs during the winter when the total national load is greater, and hence when a substantial part of the electricity bill will comprise maximum demand charges. The most convenient method to adopt is to calculate the annual load factor. Generally, peak-lopping is attractive for load factors under 30 per cent.

10. Close attention to methods of improving the annual load factor could prove more rewarding than peak load reduction.

Cost per unit generated

11. The cost per unit generated will usually exceed the unit charge of the public supply, and accordingly the generator should only be used for the periods necessary to achieve the most economic reduction in the maximum demand charge.

12. In determining the cost per unit generated it is necessary to take into account the annual capital cost in addition to fuel, lubrication, labour and maintenance cost.

13. Since the plant will be provided primarily for standby purposes, it is reasonable to base the capital depreciation charge on the additional cost associated with the use of the plant for peak load reduction purposes only. This will include such items as bulk fuel storage, synchronising equipment, additional switchgear, contact maximum demand meter, etc.

14. For estimating purposes a typical cost per unit generated can be taken as 1p based on fuel currently (1972) at 7p per gallon, and lubricating oil at 80p per gallon and including a figure of 0·3p per unit for depreciation or additional capital cost.

Size of generating plant

15. As previously stated, electricity boards will not encourage small peak-lopping schemes in parallel with their systems. It should also be borne in mind that the additional capital cost involved in adapting standby generating plant for peak-lopping will not be directly proportional to the plant size, particularly with such items as automatic synchronising and control equipment. Consequently it is doubtful whether the adaptation of plants of 250 kW or less would be justified.

Additional equipment and circuit arrangements

16. Where plant is to be used for peak load reduction it may be desirable to install two separate smaller plants having a total similar capacity rather than one larger set. This, in addition to safeguarding against the failure of one machine, will also ensure that capacity can be available during servicing periods.

17. Where two separate generating sets are provided it is important that they are suitable for parallel working and that switching facilities are provided to enable either or both of the sets to be connected to the load.

18. A pre-set maximum demand relay or equivalent device will be required to control the starting and stopping of the generator set and automatic synchronising equipment will be necessary to synchronise the generator output with the supply mains.

19. A typical schematic circuit is shown in Figure 12.

20. An alternative arrangement to having the generator output in parallel with the main distribution busbars would be to arrange for the generator to supply a specified part of the load during peak periods. This arrangement eliminates the need for synchronising equipment but automatic change-over switching will be necessary and the switching should be delayed until the generator has reached its full load operating speed in order to minimise the break in supply. Figure 13 shows a typical circuit.

21. Where the load includes equipment which incorporates a no-volt release, the action of the release should be delayed sufficiently for the period during which the change-over switch is operating. Figure 14 shows a typical arrangement.

22. Where change-over switching is used, the load factor of the generator is likely to be much lower, and the overall peak load reduction may be considerably less than the full load rating of the generator. It may, however, be possible to use plant of smaller capacity than that suggested in paragraph 15.

23. The increase in running resulting from use of generating sets for peak load reduction will make it necessary to provide bulk fuel storage adjoining the engine room, together with an electric generator transfer pump and float-operated valves in the daily service tank.

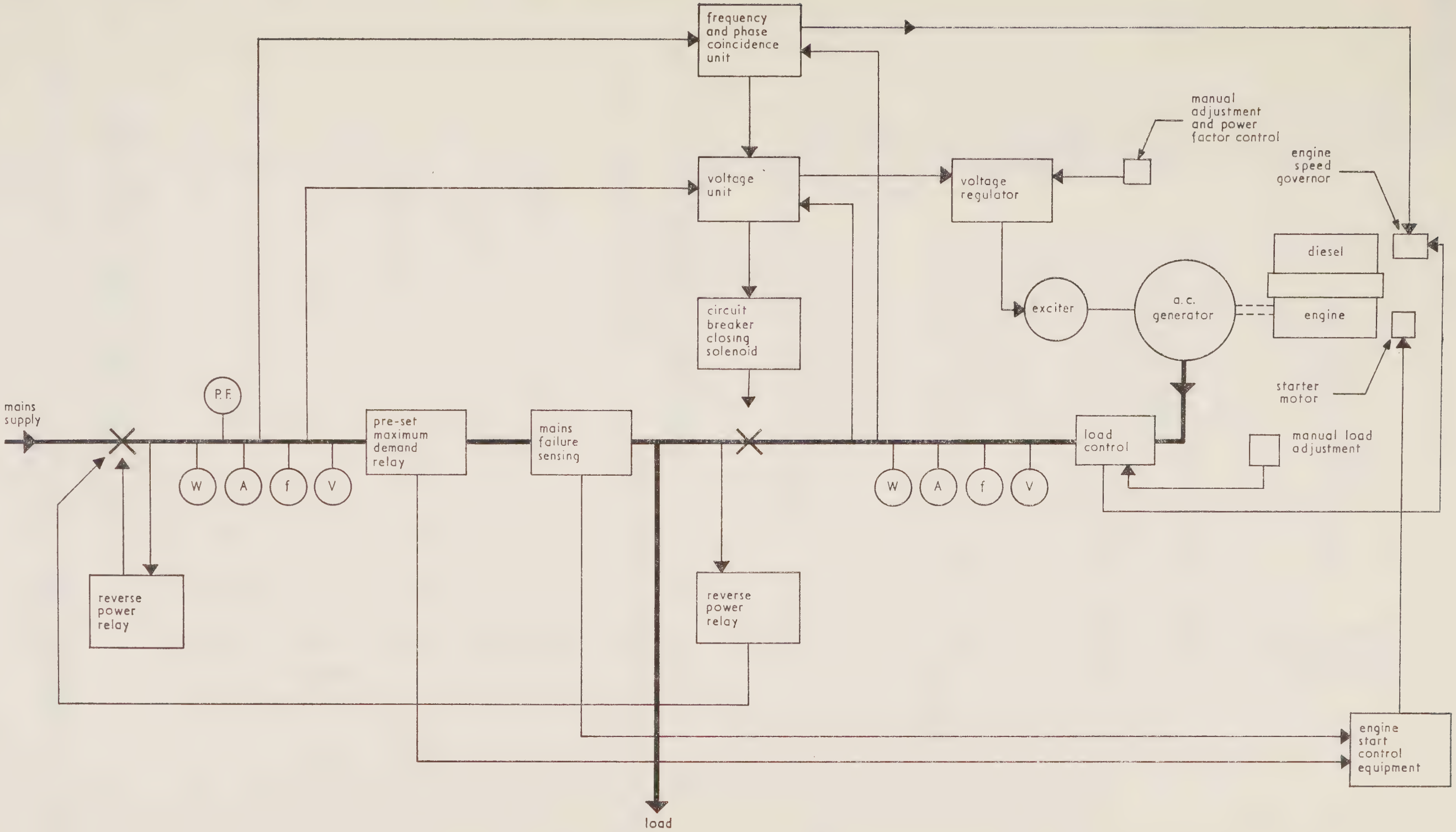
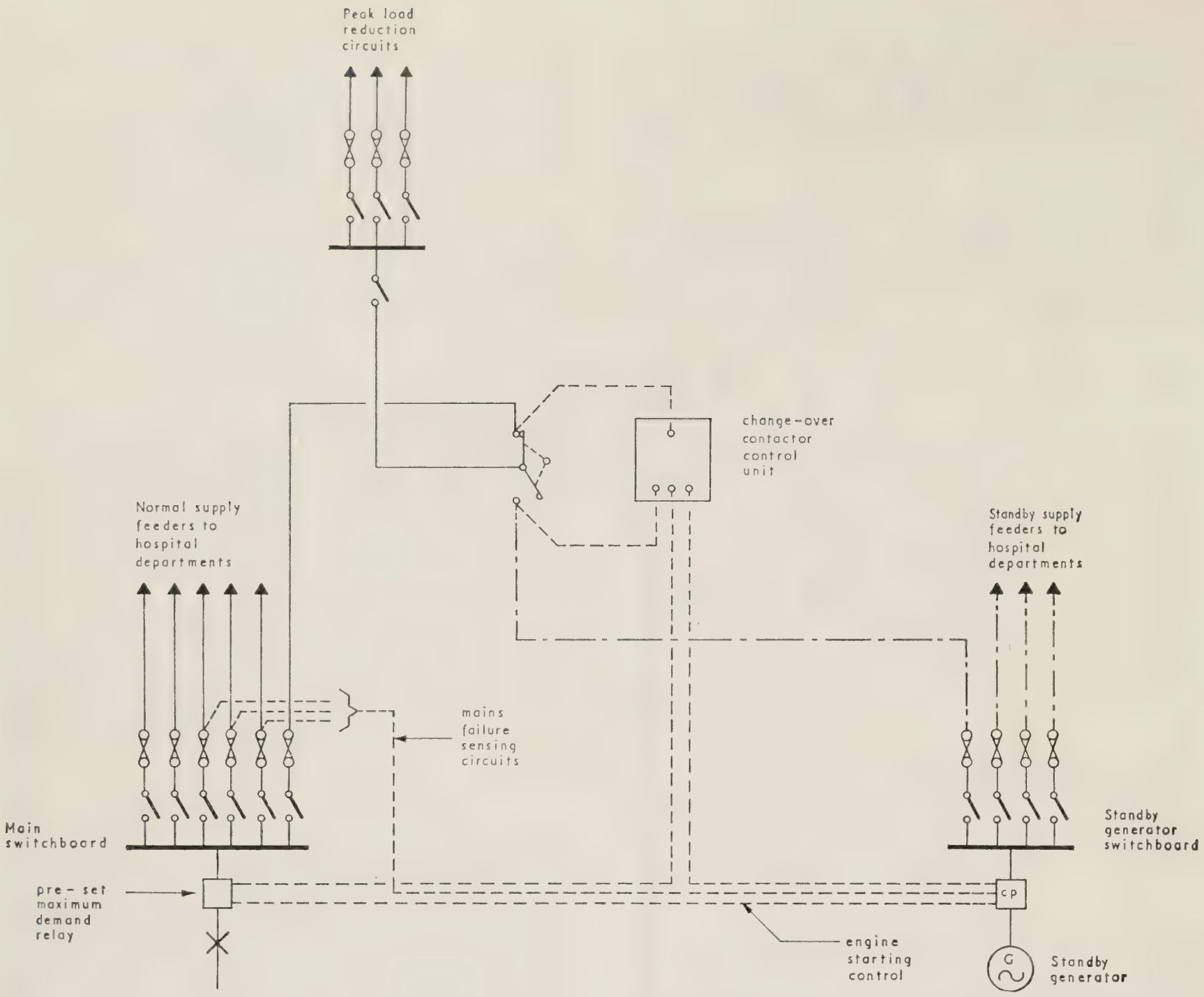
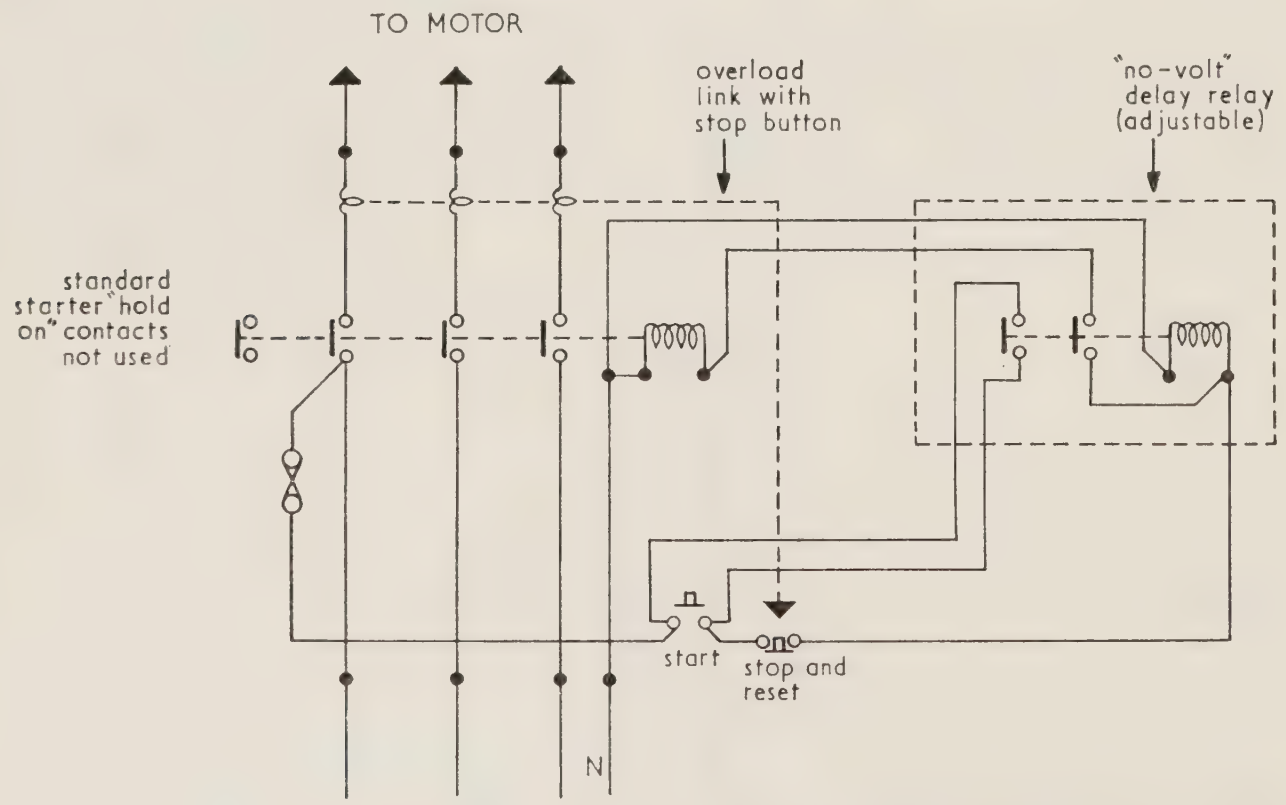


Figure 12. Controls for automatically synchronising a diesel generator with the mains supply.



NOTE: Single-line representation isused in this diagram for single and 3-phase distribution.

Figure 13. Basic diagram for automatic peak load reduction with the generator supplying selected circuits.



NOTE: the "no-volt" delay relay to close rapidly and have adjustable time delay in opening. This diagram relates to peak load reduction by supplying selected circuits, as indicated in Figure 13.

Figure 14. Connections for the automatic reclosing of a motor starter connected to a peak load reduction circuit, following the operation of the main change-over contactor.

References

British Standards Institution

B.S.89:	Electrical indicating instruments.
B.S.417:	Galvanised mild steel cisterns, tanks, etc.
B.S.440:	Stationary batteries.
B.S.649:	Diesel engines.
B.S.764:	Automatic change-over contactors.
B.S.775:	Contactors.
B.S.799:	Oil-burning equipment.
B.S.822:	Terminal markings for electrical machinery and apparatus.
B.S.1649:	Guards for shaft couplings.
B.S.1710:	Identification of pipelines.
B.S.2613:	Electrical performance of rotating electrical machinery.
B.S.2709:	Electrical performance of semi-conductor rectifiers (metal-rectifiers).
B.S.2771:	Electrical equipment machine tools.
B.S.2869:	Oil fuels.
B.S.3535:	Safety isolating transformers.
B.S.3938:	Current transformers.
B.S.3941:	Voltage transformers.
B.S.4999:	General requirements for rotating electrical machines.
B.S.6231:	P.V.C. insulated cables for switchgear and control gear wiring.

Codes of Practice (issued by B.S.I.)

C.P.3:	Chapter III: Sound insulation and noise reduction.
C.P.1007:	Maintained lighting for cinemas.
C.P.1008:	Maintenance of electrical switchgear.
C.P.3002:	Oil firing.

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5 Steam boiler plant instrumentation 7½p (10p)
6 Protection of condensate systems: filming amines (revised 1970) 7p (9½p)
7 Electrical services—supply and distribution *Temporarily out of print*
8 Safety code for electro-medical apparatus (revised 1969) 25p (28½p)
9 Pneumatic tube communication systems 7½p (10p)
10 Pressure steam sterilizers (revised 1968) *Temporarily out of print*
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